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SOUTH KENSINGTON.

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METEOROLOGY, INCLUDING TERRESTRIAL MAGNETISM

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PHYSIOGRAPHY, PART II.

METEOROLOGY, INCLUDING TERRESTRIAL MAGNETISM.

CONTENTS.

A.—Barometers.

1. *Mercurial.*

1. Open Cistern Mercurial Barometer. Made by Ramsden. (Imperfect.)
1893. *Lent by the Royal Society.*

In the description of the Royal Society's instruments by Cavendish this barometer is referred to. See *Philosophical Transactions for 1776.*

The internal diameter of the tube is given as about ·25 inch, the depression of the mercury from capillarity as ·05 inch, and the limit of the capacity error as about $\frac{1}{100}$ inch.

2. Open Cistern Mercurial Barometer. Made by Newman under the direction of Sir H. Davy.
1893. *Lent by the Royal Society.*

Correction is made for capacity error by means of an iron plunger which is of the same diameter as the interior of the barometer tube, and is made to dip into the mercury of the cistern. When the vernier is raised or lowered for taking readings, the plunger is moved simultaneously, but in a contrary direction, by the action of a pinion and a double rack. Thus any decrease or increase in the amount of mercury in the cistern, consequent on a rise or fall of the barometer, is compensated for by the greater or less extent to which the plunger is immersed. There is a thermometer attached to the case of the instrument, its bulb being placed in the cistern.

3. Open Cistern Mercurial Barometer. Made by Newman, under the direction of Dr. Daniell. (Imperfect.)
1893. *Lent by the Royal Society.*

The tube has a large bore (0·53 in.), hence the error from capillarity is small. The correction to be applied for the capacity of the cistern is $\frac{1}{100}$ of the distance above or below the neutral point, which is given on the instrument as 30·576. A scale, originally affixed to the case of the tube, enabled the reduction of the readings to 32° F. to be readily effected.

The ivory float with marked stem shews the change of level of the mercury in the cistern with the rise or fall of the barometer.

The thermometer is marked with the Reaumur and Fahrenheit scales, and its bulb dips into the mercury of the cistern. See *Meteorological Essays and Observations, by J. Frederic Daniell, F.R.S., 1823. Science Library, Victoria and Albert Museum.*

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4. Marine Barometer by Bate.

1894. *Lent by the Meteorological Council.*

To prevent too rapid oscillations of the mercury during stormy weather, the bore of the tube is contracted in the central part and the whole instrument supported by a spring arm.

5. Mountain Barometers, old forms (2) by West and Dollond respectively.

1893. *Lent by the late G. J. Symons, F.R.S.*

These instruments are contained in walking sticks, and have screw adjustments for transferring the mercury from the cistern to the tube, to render the barometers more portable.

6. Standard Barometer on Fortin's principle; reads by vernier to $\frac{1}{500}$ of an inch.

1885. *Made by Elliott Bros.*

The graduations in this instrument are made from the tip of the ivory pointer in the cistern, which indicates the position of the zero of the scale.

Before a reading is taken, the surface of the mercury is brought into contact with this tip by means of a screw at the bottom of the barometer, which, acting on an inner flexible base of the cistern, raises or lowers the contents. Readings then obtained give the height from the surface of the mercury in the cistern, and capacity error is thus eliminated.

The barometer tube is supported by a bracket and supplied with a ring and clamping screws, so that it can be readily fixed in a vertical position.

7. Wallis's Barometer Adjunct for use with the Fortin Barometer in adjusting the level of the mercury in the cistern before taking a reading.

1893. *Lent by L. Casella.*

8. Portable Pediment Barometer, with rack-work vernier to read to $\frac{1}{100}$ in. Thermometer attached to the front of the instrument with Fahrenheit and Centigrade graduations.

1890. *Lent by Elliott Bros.*

9. Portable Pediment Barometer, with sliding vernier to read to $\frac{1}{100}$ in.

1888. *Lent by P. Harris & Co.*

10. Stanley's Barometer, with tube of $\frac{3}{8}$ in. bore. Reads by rack-work vernier to $\frac{1}{100}$ in. A thermometer is attached to the stand.

1893. *Lent by W. F. Stanley.*

11. Photograph of a Portable Barometer, made by M. Herbst for the Topographical Department of the Russian General Staff, St. Petersburg, 1872.

1877. *Given by the Pulkowa Observatory.*

12. Drawing of a Normal Barometer and Manometer of the Central Physical Laboratory, St. Petersburg, after the design of Wild. Constructed by Brauer, St. Petersburg.

1877. *Given by Dr. H. Wild, Director of Central Physical Observatory, St. Petersburg.*

13. Barometer, Diagonal (about 1750) Watkins and Smith, London.

1876. *Lent by the Hydrographic Department of the Admiralty.*

In this barometer, the tube is bent a little over half way along its length through an angle of about 80°. By this method of construction an open scale is obtained, as any changes in barometric pressure would be indicated by larger spaces in an inclined than in a vertical tube.

A graduated scale, corresponding to a rise or fall of 3 inches, is placed at the side of the upper part of the tube; there is also an index, capable of movement along a stiff wire, running parallel to the tube.

Mounted on the same board is an alcohol thermometer, with its scale graduated in degrees Fahrenheit. There is also an index fixed to this similar to the one mentioned above.

The space between these two instruments is filled up with a card headed "A perpetual Regulation of Time." From this the Days of the Month, Zodiacal Signs, Sun's Right Ascension, Declination, and time of Rising and Setting, High Water at London Bridge, and Phases of the Moon, can be found.

14. Glycerine Barometer.

E. 218.--1877. *Made by Jas. B. Jordan.*

This instrument is designed for the purpose of affording a delicate "weather glass," indicating small changes of pressure by large oscillations of a fluid column, at the same time preserving

all the accuracy of the mercurial barometer. The fluid used is glycerine, in a maximum state of purity, which has a specific gravity of 1·26, or about one-tenth that of mercury. It has the advantage of giving a vapour of very low tension in the Torricellian vacuum from its high boiling point, and is therefore free from the masking effect of back pressure which interferes with the indications of a water barometer. The fluctuations of the column are observed in a glass tube of 1 inch sectional area, or 100th that of the cistern. The tube forming the body of the instrument is an ordinary composition gas pipe, ⅝ in. diameter and 27 feet long, placed in the well of the staircase, between the upper and lower galleries. The exposed surface of the glycerine in the cistern is protected by a layer of paraffin oil, in order to prevent absorption of moisture from the atmosphere.

The divided scale on the right hand side is in inches and tenths in absolute measure, while that on the left shows the equivalent values reduced to a column of mercury.

15. Syphon Barometer, with spiral connecting tube of small diameter containing an air bubble. If the barometric pressure falls half an inch the barometer falls a quarter of an inch. The bubble moves as many quarter inches as the sectional area of the vertical tube is greater than that of the connecting tube.

1885. *Lent by the late Professor F. Guthrie, F.R.S.*

16. Photograph of the Barometrograph constructed in the latter part of the 18th century by Fontana.

1877. *Given by the Royal Institute of "Studii Superiori," Florence.*

Felice Fontana, a native of Roveredo in the Tyrol, was the first Director of the Royal Museum of Physical Science and Natural History, founded in Florence by the Grand Duke Pietro Leopoldo.

A float on the surface of the mercury of a large barometer transmits its motion to a cylinder about 70 mm. in diameter, and covered with paper. Every hour an impression is made upon this paper by a steel point set in motion by a clock. The point itself advances a certain distance at each impression, so that its indications end by drawing on the paper a curve of the barometrical oscillations.

17. Milne's Barograph. Made by West; clock supplied by Schoof.

1894. *Lent by the Meteorological Council.*

The record is obtained by a float placed on the mercury of the cistern of a syphon barometer and connected with the short arm

of a horizontal lever, the long arm of which carries a pricker. A small hammer, actuated by the clock train, drives this pricker every hour against a paper which travels along to receive the record, and the series of indentations thus made shews the fluctuations in barometric pressure. The paper is ruled for tenths of an inch, and estimations of smaller amounts can be readily made owing to the long range afforded by giving the greater length to the recording arm of the lever.

18. Kreil's **Barograph**, formerly in use at the Kew Observatory, for registering the movement of the barometer.

1876. *Lent by the Kew Committee of the Royal Society.*

An instrument employed at the Kew Observatory in 1845, for the purpose of registering automatically the height of the barometer. It consists of a syphon barometer, having a float resting upon the surface of the mercury in the open end of the tube. Immediately above the tube a lever is fixed horizontally, and a cord, wrapped round a sector on the short arm, passes down and is attached to the float. The other end of the lever carries an ordinary pencil, which, being struck every five minutes by a hammer moved by a clock, makes a dot upon a sheet of paper fixed to a frame drawn in front of it by clockwork.

19. Ronalds' Photo-Barometrograph, for registering photographically the changes in the height of the barometer, formerly erected at the Kew Observatory.

1876. *Lent by the Kew Committee of the Royal Society.*

An instrument for registering the variation in the height of the barometer upon a daguerreotype plate; constructed in 1847 by Mr. Francis Ronalds, afterwards erected at the Kew Observatory, and described by him in the British Association Report for 1851.

The light from an argand lamp, after passing through a condensing lens, falls on a narrow slit cut in a metal plate attached to a barometer tube, the mercury in which, by rising or falling, varies the length of the slit illuminated.

An achromatic combination of lenses, by Voigtländer, throws a magnified image of the bright slit upon an aperture in the case, past which a daguerreotype plate is moved slowly by clockwork, and so registers the changes in the height of the barometer.

The barometer itself, together with the cistern, which is of large area, is suspended from an arrangement of levers and zinc rods, on the principle of the gridiron pendulum, in such

a manner as to render the indications unaffected by fluctuations of temperature.

An improved form of this instrument, in which the photographic image is impressed upon paper, is in use at many observatories.

20. Barograph, Mercurial.

E. 5.—1878. *Made by M. Redier, Paris.*

This has a syphon barometer, with a float resting on the surface of the mercury in the cistern. The movement of the float, with fluctuations of air pressure, is transferred by means of a clock train and levers to a pencil which gives a magnified record on the paper of the revolving cylinder of the variations in height of the mercury. The method of action of the clock train and levers is similar to that of the Regulator of Electric Currents by M. Redier, described in the catalogue of the Physical Section.

21. Drawing of a Balance Barograph, with temperature compensation according to a design by Wild. Constructed by Hasler of Berne.

1877. *Given by Dr. H. Wild, Director of Central Physical Observatory, St. Petersburg.*

In this instrument the recording is effected, at intervals of ten minutes, by electrical action.

22. Chrono-Barometer, designed by W. F. Stanley. The rise of 1 in. of mercury in the Barometer Pendulum accelerates the clock about 949 beats per day.

E. 82.—1886. *Made and given by W. F. Stanley.*

The rise or fall of the mercury raises or lowers the centre of gravity of the pendulum, thereby causing an acceleration or retardation of its swing, and the change is indicated by the dials. The registration during a day or for any period of time of a high or low number of oscillations would represent a high or low average for the height of the barometer for that time.

2. *Aneroids.*

23. Aneroid Barometer, 8 inch, showing the mechanism. Marked as a weather glass.

E. 219.—1877. *Made by R. Deutschbein, Hamburg.*

In this form of aneroid the action depends upon the changes that take place, as the atmospheric pressure varies, in the form of a

thin metallic vessel which is partially exhausted of air. This vessel has its surface corrugated in concentric circles to make it yield more easily to external pressure, and is furnished with a system of springs, levers, &c., by which the movements of the surface, resulting from variations in air pressure, cause an index to travel round a dial.

24. Aneroid Barometer, 8 inch. Marked as a weather glass. Visible movement.

1893. *Lent by L. Casella.*

Similar in principle to No. 23, but differs somewhat in the mechanism by which the movements of the surface of the metallic vessel are conveyed to the index.

25. Aneroid Barometer, 4½ inch. Marked as a weather glass.

1875. *Lent by F. Darton & Co.*

26. Aneroid Barometer, 5 inch, with altitude scale to 4,000 feet. For the use of surveyors.

1893. *Lent by W. F. Stanley.*

27. Aneroid Barometer (Field's Engineering), 2 inches diameter; reads to 4,500 feet.

1893. *Lent by L. Casella.*

This aneroid can be adjusted for changes in the density of the air arising from variations of temperature.

It is set for observation by turning the altitude scale until the number at the side of the case corresponding to the temperature reading is brought into coincidence with the index above it.

28. Aneroid Barometer with dial of 1½ mètres. For use at public buildings.

E. 3.—1878. *Made by M. Redier, Paris.*

The index of the dial is actuated by a small aneroid connected through a lever with a clock having two trains which work in reverse directions. When air pressure is stationary the fans of the two trains are held fast by the cross piece of the levers, but with a rise or fall of the pressure one or other of the fans is released and its train thus freed to turn the index round the dial.

29. Aneroid Barometer, 2 inch, compensated. Altitude scale to 7,000 feet.

1893. *Lent by L. Casella.*

30. Aneroid Barometer, 2½ inch. Altitude scale to 8,000 feet.

1875. *Lent by Pastorelli & Co.*

31. Aneroid Barometers (2); with visible movement. In these instruments the change of air pressure is indicated by means of Bourdon's tubes.

E. 446 and 447.—1877. *Made by E. Bourdon, Paris.*

This is a modification, introduced by M. Bourdon in 1850, of the ordinary form of aneroid, an elastic flattened tube, exhausted of air and bent into the form of a circle, taking the place of the metallic box. A tube of this form has the property of opening out when air pressure is diminished and of closing up when pressure is increased. This property is made use of to turn, with the aid of suitable mechanical contrivances, an index round a dial.

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32. Sympiesometer for use at sea.

1893. *Lent by L. Casella.*

This is a Boyle's tube with bulbs at its extremities. It contains a volume of hydrogen in the upper part of the longer branch, and a liquid—in this case coloured sulphuric acid—in the lower part and in the shorter branch.

Air has access to the lower bulb, and by the aid of its pressure on the surface of the liquid both the weight of the column of liquid and the pressure of the gas in the longer branch are balanced. With a change of barometric pressure equilibrium is disturbed, and a variation in the heights of the liquid in the two branches takes place. Correction for temperature being made, the height of the barometer can be found from the height of the column in the longer branch.

In the sympiesometer, correction for temperature is effected mechanically by a sliding scale to represent inches. This scale is moved along the temperature graduations till its index is in line with the number which corresponds with the reading given by the thermometer; the graduation on the sliding scale in line with the top of the column of liquid will then show the height of the barometer.

The tube of the sympiesometer exhibited has its bore contracted in the lower part to lessen the oscillations of the liquid in stormy weather.

Hydrogen is used in preference to air for the contained gas as giving a more open scale.

The revolving disc at the bottom of the case can be set to record the pressure at each observation.

B.—THERMOMETERS.

33. Photographs of Old Thermometers; a small alcohol thermometer, with Florentine scale, and four larger ones by Micheli du Crest (1754).

1877. *Given by Prof. Hagenbach-Bischoff, Director, The Physical Institute in the Bernoullianum, Basle.*

In these alcohol thermometers, zero indicates the temperature of the cellar under the Observatory of Paris, and 100° the boiling point of water.

34. Rutherford's Maximum and Minimum Thermometers.

1893. *Lent by the Royal Meteorological Society.*

These instruments, the invention of Dr. Rutherford, were first described in the Transactions of the Royal Society of Edinburgh for 1794.

35. Old Mercurial Thermometer by Adams of Fleet Street. Scale 14 in. long, graduated from −30° to 700° F. The melting points and boiling points of various substances are shewn on the scale.

1893. *Lent by the late G. J. Symons, F.R.S.*

36. Old Mercurial Thermometer by Dollond. Scale 24 in. long, in two parts, graduated from —20° to 535° F.

1893. *Lent by the Royal Society.*

37. Old Mercurial Standard Thermometer by Troughton and Simms. Brass divided scale, 15 in. long, graduated from zero to 215° F.

1893. *Lent by the Royal Society.*

38. Balloon Thermometer, graduated from —10° to 105° F. Made by L. Casella.

1894. *Lent by the Meteorological Council.*

This thermometer was constructed with a view to extreme sensitiveness, in order to obtain with it accurate records of the temperatures of the layers of air through which a balloon might be rapidly passing.

For this object the bulb, which is long and of narrow bore,

was made of thin glass, and mounted fully exposed, to allow the air free access to all sides of it.

Its delicacy of construction, however, renders this form of thermometer very liable to damage from the bumping which sometimes accompanies balloon descents.

39. Negretti and Zambra's Mercurial Minimum Thermometer. (Imperfect.)

1893. *Lent by the late G. J. Symons, F.R.S.*

These instruments are made of more than ordinarily wide bore, to allow a steel index pointed at both ends to move freely in the tube.

When set for observation, the thermometer is put in an upright position, and the index brought to the level of the mercury.

With any contraction of the column, the index falls by its own weight, but with expansion, it is forced to the side of the tube, the mercury passing beyond it. The upper end of the index indicates the temperature.

The magnet serves to bring the index into position; the bulb at the top of the tube is used as a receptacle for the mercury, when, owing to the weight of the column, there is a difficulty in moving the index.

40. Six's Thermometer, named after its inventor, Mr. Six of Canterbury; for registering extremes of temperature.

1876. *Lent by Dring and Fage.*

The indexes are little pieces of steel coated with glass which are enabled to retain their position in the tube by means of a hair fastened round them, and by this means the highest or lowest temperature is recorded.

41. Six's Thermometer with a very flat bulb which renders it as sensitive as an ordinary mercurial thermometer.

1876. *Lent by S. G. Denton.*

42. Phillips's Maximum Thermometer.

1893. *Lent by L. Casella.*

In these instruments the index is a portion of the mercurial column which is separated from the remainder by an air bubble. Of the two ends of the index, the further from the bulb indicates the temperature.

43. Minimum Thermometer, with flat bulb.

1876. *Lent by Dring and Fage.*

Constructed with a view to overcome the great drawback to the use of spirit thermometers, sluggishness. The bulb is made flat, so as to expose as large a surface as possible, while the glass is made as thin as is consistent with a non-barometric action.

44. Minimum Alcohol Thermometer on Rutherford's principle.

1893. *Lent by L. Casella.*

45. Minimum Alcohol Thermometer on Rutherford's principle. Bulb forked to increase the sensitiveness of the instrument.

1893. *Lent by L. Casella.*

46. "Thermomètre Fronde."

1893. *Lent by L. Casella.*

The air temperature is ascertained by placing the thermometer in its perforated case and swinging it round the head by a cord. By this method more accurate results are obtainable than by exposure on stands of ordinary construction.

Some notes by R. H. Scott on the use of the Thermomètre Fronde on board ship will be found in the *Royal Meteorological Society's Quarterly Journal*, 3, 1877.

47. Symons's Earth Thermometer, and tube for obtaining temperatures to any depth.

1893. *Lent by L. Casella.*

A pointed iron tube is driven into the ground to the depth whose temperature is being ascertained, and a slow action thermometer is suspended within it by a chain attached to the copper cap of the tube. The thermometer, which reads from 25° to 95° F., is protected by a box-wood casing.

The usual sizes for the tubes are 6 inches, 1 foot, 2 ft., 3 ft., 4 ft., 6 ft., 10 ft.

48. Balfour Stewart's Fluctuation Thermometer.

1876. *Lent by the late Prof. Balfour Stewart, F.R.S.*

This is formed of two tubes of different bores connected by a bulb in the centre. When set in a horizontal position, an increase of temperature causes the mercury in the wider tube to move from the bulb towards the end, but with a decrease of temperature the mercury in the narrower tube moves towards the

bulb. Thus with all changes there is a movement of the mercury in the direction of the extremity of the wide tube.

Attached to the stand is a scale in two parts, graduated from 0 to 180, by means of which the amount of fluctuation for any interval of time can be ascertained. The thermometer can be set for observation by standing it on end. See *Balfour Stewart's Elementary Treatise on Heat.*

49. Chrono-Thermometer, for registering temperature cumulatively. The expansion of the mercury by 1° F. accelerates the clock about 17·5 beats per day.

E. 83.—1886. *Given by W. F. Stanley.*

The rise and fall of the mercury in the thermometer pendulum raises or lowers its centre of gravity, thereby causing an acceleration or retardation of its swing, and the change is indicated by the dials. The registration during the day or for any period of time of a high or low number of oscillations would represent a high or low average for the height of the thermometer for that time.

50. Thermometer Screen for one minimum thermometer. In use at stations belonging to the Norway Meteorological Institute.

1876. *Lent by Prof. H. Mohn, Christiania.*

Made of sheet iron with double walls, suspended on a cylindrical rod intended to pass through the window frame. The rod has a handle inside, so that the screen with the thermometer can be turned for "setting" in the same way as a thermograph.

The double walls prevent the rising of the thermometer even in direct sunshine to more than a few degrees above that caused by the air. The minimum thermometer was made by R. Grave of Stockholm, and the screen was executed after the design of Prof. H. Mohn.

51. Thermometer Screen for meteorological stations of the 2nd order. In use at the stations of the Norway Meteorological Institute.

1876. *Lent by Prof. H. Mohn, Christiania.*

Made of sheet iron. To be mounted outside a window and kept in shade. The screen contains one psychrometer (dry and wet bulb), one minimum thermometer (both instruments made by R. Grave of Stockholm), and one hair-hygrometer (made by Herman and Pfister of Berne). The screen is constructed after the designs of Prof. H. Mohn.

52. Thermometer Screen for one single thermometer, for obtaining the temperature of the air. In use at stations belonging to the Norway Meteorological Institute.

1876. *Lent by Prof. H. Mohn, Christiania.*

Made of sheet iron. To be mounted outside a window or on a wall, and kept in shade. With thermometer, made by R. Grave of Stockholm. Screen constructed after the design of Prof. H. Mohn.

C.—Sunshine-Recorders and Apparatus for Measuring the Heating Effect of the Direct Solar Rays.

53. The original Photographic Sunshine-recorder of Prof. H. McLeod.

1885. *Lent by Prof. H. McLeod, F.R.S.*

The sunlight is reflected from the silvered bulb of a flask, and then focussed by means of a double convex lens on the sensitized paper contained in the camera. In taking observations, the axis of the apparatus must be set parallel to the earth's, and the recording paper adjusted in accordance with the sun's declination.

This adjustment of paper is necessitated by alteration in the position of focus caused by reflection of the sun's rays from different parts of the bulb of the flask.

The record obtained is circular, and is marked for the hours, when the position of the meridian line has been determined, by drawing radial lines at intervals of 15°. Ferroprussiate paper is used for the records, which are fixed by placing them in water for a few minutes. Examples of the traces, divided for the hours, are exhibited with the instrument. For fuller information, see *Journal of the Physical Society, Vol. vi. p. 216.*

(The McLeod Sunshine-recorder sold by dealers is a modified form of that exhibited.)

54. Jordan's Single-cylinder Photographic Sunshine-recorder.

1886. *Made by Negretti and Zambra.*

The dark chamber is a brass cylinder, mounted on a bronzed stand having a latitude arc, and pierced with a small rectangular aperture on each side to admit the sun's rays to act on the sensitized paper within the cylinder.

When set for latitude and placed in the meridian, the mid-day

rays of the sun passing through the two apertures should fall at equal distances on each side of the 12 o'clock line of the recording paper.

These papers are divided into hours and sixths, the cyanotype process being used in sensitizing them. The record is fixed by rinsing the chart in cold water for a few minutes. For fuller description, see *Quarterly Journal of the Royal Metereological Society. Vol. xii.*

55. Jordan's Twin-cylinder Sunshine-recorder.

1893. *Made by Negretti and Zambra.*

This is an apparatus for photographic registration and is an improvement on Jordan's Single-cylinder Instrument.

It consists of two half-cylinders or chambers of brass, set with their axial planes outwards at an angle of 60°, and hinged to a stand having a latitude arc.

At the sides are two small rectangular apertures, one in the centre of each of the axial planes, for admitting the sun's rays. One half cylinder is for the morning record, the other for the afternoon.

When correctly placed in the meridian, the sun's rays at noon should fall on the 12 o'clock line of the sensitized chart in each chamber.

Amongst the advantages claimed for this instrument over the Single-cylinder Recorder are:—

1. The trace obtained is in a straight line at right angles to the hour lines, and so can be readily measured.
2. The aperture is so placed in each chamber as to allow of the admission of earlier and later rays.
3. The amount of diffused light admitted to the chamber is reduced by having but one aperture.

56. Photographic Sunshine-recorder, designed by Dr. J. Maurer.

1893. *Made and lent by Th. Usteri-Reinacher, Zurich.*

The dark chamber is a bronzed brass cylinder, with its top oblique to the axis and pierced with a small rectangular hole. The bottom of the cylinder is removable to allow of the adjustment inside of the recording sensitized papers. A small latitude arc is placed under the instrument and the whole is supported on an iron stand.

If the cylinder be fixed with its axis adjusted for latitude and its North-South line in the meridian, the sun's rays passing through the hole at the top, leave a record of their course on the sensitized paper. As this record is approximately a straight line at right angles to the hour lines engraved on the paper, the duration of sunshine for any particular day can be readily ascertained.

The record should be placed in water, after its removal from the cylinder, for about ten minutes, in order to fix it.

57. Campbell's bowls for sunshine recording, used at the Kew Observatory 21st December, 1891 to 21st June, 1892, and from June, 1892 to December, 1892.

1894. *Lent by the Meteorological Council.*

These bowls are made of mahogany, of as nearly as possible the same quality, In the bowl is placed a spherical water or glass lens, whose centre coincides with the centre of the cavity in which the lens rests.

Through the concentration of the sun's rays, a record of its course is burnt into the wood, the position of the record rising or falling in the bowl according to the sun's declination.

A measurement of the amount of wood burnt out during different periods gives the relative heating powers for these periods.

The bowls exhibited show the difference in the sun's heat tor the two halves af the year falling between the solstices.

58. Herschel's Actinometer. Used by Sir J. Hooker in his investigations when travelling in the Himalayas.

E. 35.—1890. *Given by Sir J. Hooker, F.R.S.*

The Actinometer consists of a glass cylinder filled with ammonio-sulphate of copper, to one end of which is connected a tube with an arbitrary scale of equal parts, while to the other end a screw is fitted which may be used to adjust the liquid in the tube, the whole forming a delicate thermometer. Through the screw is passed to the inside of the cylinder the bulb of an alcohol thermometer, by which the temperature of the liquid is ascertained.

By noting on the arbitrary scale the height of the liquid immediately before and after the instrument has been exposed to the sun's rays for a definite time, and also making similar observations when it is set in the shade, a measure of the heating effect of the sun's rays can be obtained. This can be corrected for the unequal expansion of the liquid with the aid of readings given by the alcohol thermometer.

Sir J. Herschel recommends that not less than three sun observations and two intermediate shade observations should be taken, the calculations to be made from the means of the readings in each position.

The unit of solar radiation adopted in the ultimate reduction of the observation was the Actine. By this is understood, "that intensity of solar radiation which, at a vertical incidence and supposing it wholly absorbed, would suffice to melt one millionth part of a metre in thickness from the surface of a sheet of ice horizontally exposed to its action per minute of mean solar time." See the article on Meteorology by Sir J. Herschel in the *Admiralty Manual of Scientific Enquiry. Science Library, Victoria and Albert Museum.*

59. Padre Secchi's apparatus for measuring the comparative intensity of the heat of the sun's rays.

1893. *Lent by L. Casella*

This is a metal vessel in the form of a hollow cylinder, 10 inches in length and of three inches diameter, filled with a liquid at any desired temperature.

In three tubulures are inserted thermometers, the bulbs of two of which are immersed in the liquid; the bulb of the third is passed through the vessel to the hollow centre of the cylinder.

For observation, the apparatus is placed on a stand and set so that the sun's rays fall on the exposed bulb. It was found that the increase in the reading shewn by the thermometer was independent of the temperature of the liquid surrounding it.

60. Pouillet's Pyrheliometer. Improved form Made by L. Casella.

1893 *Lent by the Rev. F. W. Stow; M.A.*

This consists of a thermometer whose bulb is immersed in the mercury contained in a small cylinder of known capacity and area of base.

When used, the base of the cylinder is turned for a definite number of minutes alternately to and from the sun, and means of the thermometer readings in each position are taken.

From these means can be determined the number of degrees that the temperature of the volume of mercury in the cylinder has been raised by the heat of the sun acting on a known area for a fixed time.

The base should be set so that the sun's rays fall perpendicularly on it, and a paper disc is supplied to show by the position of the shadow of the cylinder when this is done.

The Rev. F. W. Stow's improvement is the outer cylindrical case to protect the thermometer tube from wind, and rays other than direct.

See *Tyndall's Heat considered as a Mode of Motion. Science Library, Victoria and Albert Museum.*

61. Stanley's Copper Pyrheliometer.

1893. *Lent by W. F. Stanley.*

The thermometer in this instrument has its bulb enclosed in a 1·4 inch copper ball, whose surface has been oxidised by heating. For observations it is supported on a black polished slate slab at a distance of about 2 in. from the surface, the slab being inclined at an angle of 45°.

It was found that readings obtained with this form of instrument were lower than with the ordinary solar radiation

thermometer, but results obtained with similarly constructed instruments were uniform.

See *Quarterly Journal of the Royal Meteorological Society, April,* 1885.

62. Southall's Helio-pyrometer.

1893. *Lent by L. Casella.*

This consists of a box lined with black cloth cushions, which contains a maximum thermometer with blackened bulb, and is closed by a glass lid.

If set so that the sun's rays fall perpendicularly on this lid, the difference of the readings of the thermometer and those obtained from a thermometer exposed in the ordinary way in the shade, will give a measure of the heating power of the sun, allowance being made for loss of heat by reflection from the surfaces of the glass.

Mr. Southall recommends 11.30 to 12.30 as the most suitable time for observations to be made, as then no change in the position of the box will be necessary.

The advantages claimed for this method of exposure over that ordinarily adopted with solar radiation thermometers are that there is no lowering of the readings by air currents and by the cooling resulting from evaporation from the soil.

With the apparatus a small vessel in which water is boiled by the sun's rays is occasionally used.

D.—Hygrometers and Psychrometers.

63. Oat-beard Hygrometer. In brass case 1¼ in. diameter.

E. 2.—1893. *Given by F. C. Bayard.*

In this, the twining and untwining of the beard of the oat is made use of to turn an index round a graduated dial.

One end of a short length of the beard is fastened to a plate at the bottom of the case of the hygrometer, and the other is secured to the index.

With humidity, by the untwining of the beard, the index is turned round the dial in the direction of a clock hand; with dryness, by the twining, the movement is reversed.

The brass case is perforated to allow the air to act freely on the beard, and is furnished at the back with a knob by which the index can be set.

The invention of the Oat-beard Hygrometer is attributed by some to Robert Hooke, and a description of it can be found in his "*Micrographia,*" published in 1667. *Science Library, Victoria and Albert Museum.*

64. Kater's Hygrometer. Made by Robinson.

1893. *Lent by the Royal Society.*

This instrument, which was invented by Capt. Kater, depends for its action on the twining and untwining, with increased dryness or dampness of the atmosphere, of the beard of the grass *Andropogon contortum.*

The beard is fastened to the cleft end of the axis of the index of the larger dial and continued in a line to the back of the case, where it is secured to a pin, which can be adjusted to give the necessary tautnesss.

The larger dial is graduated in 100 parts; the smaller dial serves to shew the number of revolutions of the index of the larger.

The case is perforated to allow of free access of air.

This hygrometer was considered to be more sensitive than that of Saussure.

A similar instrument is fully described in the *Encyclopædia Britannica, 7th Edition, in the article on Hygrometry. Science Library, Victoria and Albert Museum.*

65. Nicolle's "Aqueous Meter."

1893. *Lent by B. C. Wainwright.*

A thin slab of wood is cut across the grain and placed in a frame furnished with a graduated arc and an index.

The axis of the index is attached to the wood in such a way that the lengthening and shortening of the slab by increase or diminution of humidity of the air causes the index to move along the arc.

The graduations range from 0° to 100°, the limit at one end being "Desiccation," at the other "Immersion."

66. Single-hair Saussure's Hygrometer, in brass frame with silvered scale.

1880. *Lent by J. J. Griffin and Sons.*

In this, the movement of the index depends on the changes, caused by variations in the humidity of the atmosphere, of the length of a hair. One end of the hair is secured at the top of the frame, the other is passed round a pulley and kept taut by a small weight. As the hair shortens the index rises to indicate dryness; when it lengthens the weight causes the index to fall, to show increased humidity.

67. Eight-haired Saussure's Hygrometer, by Richer of Paris, formerly the property of Mr. Francis Ronalds, and used by him at the Kew Observatory in 1843.

1876. *Lent by the Kew Committee of the Royal Society.*

68. Klinkerfues' Bifilar Hygrometer, with percentage scale of humidity.

E. 221.—1877. *Prof. Klinkerfues, Göttingen.*

A wisp of hairs is passed through holes at each end of the small cross bar of the spindle which carries the index, and the ends of the wisp are made fast to a plate in the upper part of the case of the instrument. A second wisp of less length is also passed, but in a contrary direction to the first, through the same holes, crossed, and the ends secured to a bar near the bottom.

By these means a twist is given to the hairs acting on the spindle and the index made to take up a position dependent upon the balance of the torsions of the upper and lower wisps.

With a change in the humidity of the atmosphere this balance is disturbed, and the change made apparent by the movement of the index towards one or other of the extremes of the scale.

A thermometer and reduction disc are supplied, by which air temperature can be obtained and dew point calculated.

For an explanation of the theory on which the construction of this instrument is based, see Klinkerfues' "Theorie des Bifilar-Hygrometers mit gleichtheiliger Prozent-Scala."

69. De Luc's Whalebone Hygrometer. Made by U. F. Hausmann. (Parts wanting.)

1893. *Lent by the late G. J. Symons, F.R.S.*

A narrow strip of whalebone, cut transversely to the fibre, is connected at one end with the bottom of the frame of the instrument, at the other with the larger of two pulleys which turn on the same axis as the index of the graduated circle.

Attached to the smaller of the two pulleys is a spring which serves to keep the strip of whalebone taut. On the lengthening of the strip by increased moisture, the spring carries the index round; on its shortening for dryness, the index is drawn by the strip in a contrary direction.

De Luc claimed that this instrument was more uniform in its action than the Saussure Hair Hygrometer.

70. Daniell's Hygrometer, graduated from 0° to 130° F.

E. 44.—1886. *Made by W. Ladd.*

This is an instrument for determining the "dew-point," or the temperature at which the aqueous vapour contained in the air begins to be condensed. It consists of a glass siphon connecting two bulbs. One of the bulbs is blackened, and contains ether, into which dips a small thermometer for the determination of the temperature of the liquid. The instrument is mounted on a stand bearing another thermometer to take the temperature of the surrounding air. The empty bulb is covered with muslin tied tightly round it. To use the hygro-

meter, a little ether is poured upon the muslin, and the cold produced by its rapid evaporation condenses the ether vapour inside the empty bulb as fast as it is formed in the blackened bulb. By this action the temperature in the blackened bulb is lowered. As soon as the dew-point is reached, aqueous vapour from the air condenses as dew on the black bulb, and at that instant the readings of the two thermometers must be observed.

71. Daniell's Hygrometer, graduated from – 20° to 120° F. Silvered bulb.

1880. *Lent by J. J. Griffin & Sons.*

72. Jones's Hygrometer with bulb at an acute angle.

1893. *Lent by the Royal Society.*

This is a mercurial thermometer which can be used to obtain both the temperature of the air and the dew point. For the latter purpose the bulb has a black, enlarged, and somewhat convex top on which the deposition of moisture is observed. The other part of the bulb is covered with silk, and over this ether is poured to lower the temperature of the mercury as in Daniell's and other condensation instruments. The thermometer, which is about 4½ inches long, is supported by a brass wire attached to the case, and can be set at any desired angle.

A hygrometer of a somewhat similar pattern, but with the bulb on an arm bent twice at right angles, to bring the bottom of the bulb uppermost, is described in the *Philosophical Transactions of the Royal Society*, 1826, *p.* 53.

73. Regnault's Hygrometer.

E. 40.—1893. *Made by Elliott Bros.*

Both the thermometer for air temperature and that for dew point are contained in glass tubes partly enclosed in silver thimbles, and are thus exposed under somewhat similar conditions.

The tube for dew point observations is about half filled with ether, through which air is drawn by an aspirator connected to a pipe in the stand of the apparatus.

The lowering of temperature by the evaporation of the ether, as the air passes through it, causes a deposition of dew on the silver thimble, and from observations of the temperature at which this deposit takes place the hygrometric state of the atmosphere is determined in the usual way.

It is claimed for this instrument that it is more accurate than Daniell's, for the whole of the ether being kept at one temperature by the agitation of the air, the indications of the dew point thermometer are more reliable. The error in the readings arising from the proximity of the observer can also be avoided by the use of a telescope.

74. Appold's Automatic Hygrometer.

1893. *Lent by the Royal Society.*

This apparatus was designed by the late J. G. Appold, F.R.S., for the registration and regulation of the moisture in the atmosphere of the rooms of his house, and was presented by Mrs. Appold to the Royal Society.

The essential part consists of a glass tube with bulbs at its extremities, which is connected to a brass rod, the whole turning on a knife edge after the manner of a balance. Mercury fills the tube and, in part, the bulbs, while in the latter also is a small quantity of ether. Half the tube and one bulb are covered with a paper which is kept constantly moist by water supplied through a pipe at the top of the case. The knife edge is placed immediately above the covered bulb, and beyond the latter is an arm carrying a counterpoise, with which and a helical spring the tube is balanced and adjusted.

With dryness of atmosphere evaporation takes place from the paper, and the consequent lowering of the temperature causes a contraction of the ether in the covered bulb. This is followed by a transference of mercury from the uncovered to the covered bulb under the influence of the pressure of the ether vapour in the former. Equilibrium is thus destroyed, and the uncovered bulb and tube rise, and, acting through a lever, open a valve which allows water to pass through a tube to some heated pipes covered with paper.

By evaporation from these pipes moisture is added to the air till the required hygrometric condition is attained.

A pencil can be made to record on paper the movements of the mercury tube, and this record can be checked by readings of the Mason's hygrometer attached to the case of the instrument.

See *Proceedings of the Royal Society, Vol. XV. Science Library, Victoria and Albert Museum.*

75. Geissler's Hygrometer.

E. 123.—1877. *Made by Dr. H. Geissler, Bonn.*

This is a modification of Daniell's instrument. The dew point and the temperature of the surrounding air are obtained from two separate thermometers mounted on one stand.

The bulb of the dew point thermometer is enlarged and answers the purpose of the blackened or silvered bulb of Daniell's instrument in making apparent the deposition of dew. On an arm at right angles to the stem is a muslin-covered bulb by means of which temperature can be lowered by evaporation.

Both thermometers are graduated to read to the fifth of a degree.

76. Hygrometer, horizontal form. Designed by the late G. Dines.

1893. *Made by L. Casella.*

This is a condensation hygrometer, and used in a somewhat similar way to that employed in taking observations with a Daniell's instrument.

Ice and water, or cold water only, are put into the small upright cistern, whence the water flows under the thermometer to a small chamber in which rests the bulb of a thermometer. The bulb and chamber are covered with a thin, smooth, black glass plate.

As the water flows out of the pipe at the further extremity of the hygrometer, the temperature of the black glass plate is lowered to the dew point, and a film of moisture is deposited on the plate. The temperature at which this deposition takes place can be noted from the thermometer, and the dew point temperature thus ascertained. This known, and the temperature of the surrounding air obtained, the hygrometric state of the atmosphere can be calculated by the usual methods.

77. Hygrometer, vertical form. Designed by the late G. Dines.

1893. *Made by L. Casella.*

In this form of instrument ether may be used, a receptacle for its storage being supplied. Cold is produced by forcing air through the ether. The deposition of moisture on the black glass plate takes place as in the horizontal instrument.

78. Psychrometer, or dry and wet bulb hygrometer, with thermometers graduated in tenths from – 28° to 46° C.

E. 122.—1877. *Designed by Dr. H. Geissler, Bonn.*

79. Psychrometer, with thermometers divided into tenths from —20° to 50° C.

E. 172.—1877.

Made by Warmbrunn, Quilitz, & Co., Berlin.

80. Psychrometers (2), one in oak frame; the other with brass support and silvered scale, on circular wood stand.

1860 & 1875. *Lent by Pastorelli & Co.*

81. Reduction Disc for Psychrometers.

E. 222.—1877. *Prof. Klinkerfues, Göttingen.*

This is an arrangement for finding mechanically the dew point temperature from the readings of the dry and wet bulb thermometers.

It consists of a circular scale above which turns a cardboard disc. From the scale is found the dew point temperature; the revolving disc is marked for dry bulb indications.

If the numbers on scale and disc which correspond to the wet bulb reading be brought into coincidence, the dew point temperature will be shown on the scale in line with that number on the disc which represents the dry bulb reading.

The coloured part of the scale must be used when the air temperature is below freezing point.

82. Psychrometer Scale, for determining the relative and absolute moisture of the air, as well as the dew-point, without calculation.

E. 223.—1877. *Designed by Prof. Prestel, Emden.*

83. Casartelli's Mill Hygrophant. Designed specially for use in weaving and spinning mills.

E. 27.—1897.

Given by J. Casartelli & Son, Manchester.

By means of this instrument the hygrometric state of the atmosphere can be ascertained directly by inspection. It consists of a dry and a wet bulb thermometer, between which is placed a case containing a scale to represent dry bulb readings and a revolving cylinder marked with percentages of moisture for each degree of difference of the two thermometers from 1° to 21°.

This difference ascertained, the corresponding column of percentages as indicated by the number at the top, is turned to the front, when, in line with the number representing the dry-bulb reading, will be found the percentage of moisture in the atmosphere at the time of observation. Saturation is represented by 100.

84. Photomicrographs of Cotton Yarns (magnified 50 diameters) shewing the advantages of having in the atmosphere of the spinning mill a due percentage of humidity.

1897. *Photographed and presented by W. W. Midgeley, F.R.Met.Soc.*

85. Six's Thermometer with mercurial wet bulb thermometer attached to the same stand, thereby combining four instruments, namely maximum, minimum, and present temperature thermometers, and hygrometer.

1876. *Lent by S. G. Denton.*

E.—Rain Gauges and Evaporimeters.

86. Rain Gauge. In use at meteorological stations belonging to the Norway Meteorological Institute.

1876. *Lent by Prof. H. Mohn, Christiania.*

Square surface, 15 × 15 centimetres, and height 60 centimetres; for catching snow; the lower part protected against evaporation. The rain (or melted snow) water is to be poured out of the gauge through one of its upper corners, into a measuring cylindrical glass, divided to show the height of fallen rain in millimetres. The gauge is made of sheet iron, after the design of Professor H. Mohn. The measuring glass was calibrated at the Meteorological Institute in Christiania.

87. Rain Gauge. (The "Bradford Water Works.")

1893. *Lent by L. Casella.*

This is a five-inch gauge of 24 inches length, with a cylinder above the funnel.

The cylinder is found of advantage in obtaining more accurate measurements, especially in the case of snow fall.

The collecting pail will hold about 15 c. inches, and the measuring jar is graduated to 1·00 c. in.

88. Rain Gauge. (The "Symons' Snowdon.")

1893. *Lent by L. Casella.*

A five-inch gauge in form somewhat similar to No. 87, but 17 in. long.

It is supplied with both collecting bottle and pail. The measuring jar is graduated to ·50 c. inch.

89. Rain and Snow Gauge. Designed by the late Jas. Sidebottom; made by J. H. Steward.

1893. *Lent by the late Jas. Sidebottom, F.R.Met.Soc.*

This is an eight-inch gauge with its lower part surrounded by a hot water jacket for melting snow. A funnel and tap are

supplied, the one for filling the jacket, the other for withdrawing the water from it.

The collecting can is protected by a box with glass front, which encloses also the lower part of the gauge. The measuring jar is graduated to ·50 c. in.

90. Hellmann's German Rain Gauge.

1893. *Lent by the late G. J. Symons, F.R.S.*

Diameter of gauge 6¼ in.; length, 1 ft. 4¼ in. Constructed to be supported above the ground by means of a stake.

91. Eight-inch Rain Gauge, tin, japanned. Constructed upon the principle recommended by Glaisher. With graduated measuring glass.

1860. *Lent by Pastorelli & Co.*

92. Rain Gauges (2) with funnels, pan, bottles and measuring glasses.

1875 & 1876. *Lent by F. Darton & Co.*

93. Rain Gauge, consisting of bottle, measuring glass and funnel.

1888. *Lent by P. Harris & Co.*

94. Rain Gauge, in copper and glass, with evaporating pan, and measuring glass.

1865. *Lent by F. Newton & Co.*

95. Ronalds' Rain and Vapour Gauge, erected at the Kew Observatory in 1843.

1876. *Lent by the Kew Committee of the Royal Society.*

An instrument constructed at the Kew Observatory in 1843 by Mr. Francis Ronalds, for indicating a mean result from the quantity of water which may have fallen between any two given periods, *minus* the quantity of vapour which has evaporated in the same time, on and from a circular plane of one foot diameter. It is described in the British Association Report for 1844.

It consists of two cylindrical vessels, connected by a tube, the one being one foot in diameter, and open at the top, whilst the other is 3 inches, and (with the exception of a small hole) entirely closed by a cover, which carries a frame, holding a circular divided arc, with an index moving over it. The index is

attached to a small pulley, over which a cord passes, having its end fixed to the float in the cylinder. This, rising and falling with the changes of water level, indicates the amount of rain or evaporation on the metal scale.

96. Crossley's Self-registering Rain Gauge.

1893. *Lent by L. Casella.*

This is a ten inch square gauge, with oscillating bucket and set of counters contained within the case. Each movement of the bucket caused by the weight of water conveyed alternately to its right and left halves by the gauge, is transmitted to the wheel work of the counters by a lever acting between two projecting plates on the bucket.

There are three counters for cubic inches, tenths and hundredths respectively.

A pipette-shaped measure is supplied for testing the accuracy of the registration. This measure will contain 5 cubic inches of water, and its contents should, as the gauge has an area of 100 sq. inches, advance the hand of the hundredths counter five divisions.

97. Crossley Rain Gauge. (East India Co.'s pattern.)

1893. *Lent by the late G. J. Symons, F.R.S.*

In this the oscillating bucket and the wheels for recording its movements are separated by a partition. The bucket, which is constructed to tilt with every tenth of a cubic inch of rainfall, actuates a pin wheel of somewhat large diameter.

The wheel is marked on its periphery by tenths from ·1 to 5 cubic inches, and as the vibrations of the bucket turn the wheel, the amount of rainfall within these limits can be read from an opening in the side of the case. For higher readings, a dial marked for 5 to 100 cubic inches, which is in connection with the graduated wheel, is used.

98. Electrical Self-recording Rain Gauge.

1893. *Lent by Yeates & Son, Dublin.*

This gauge is similar in principle to Crossley's, but consists of two distinct parts, the gauge and the recorder.

The former, which is fitted with a funnel, is of square section and of 10 in. side.

The rain collected by the gauge passes by the funnel to an oscillating bucket, so made and supported that the weight of a cubic inch will cause it to tilt to discharge its contents.

This act of tilting is made use of to record the amount of rain received.

The recorder has two dials, graduated to read to cubic inches and hundredths, and is supplied with a train of wheels, the

movement of which is controlled by the armature of a pair of electro-magnets.

The gauge, the recorder and a battery being connected by wires, the oscillation of the bucket completes the circuit, and the electro-magnets, acting by their armature, move forward the hand on the dial.

A record of each one hundredth of a cubic inch of rain is thus obtained.

The advantage of this system is, that the recording dials may be kept in the house, and thus preserved from damage by exposure, while at the same time they may be readily consulted.

99. Watson's Evaporation and Rain Gauges.

1893. *Lent by the late G. J. Symons, F.R.S.*

These are circular copper vessels of 10 in. diameter which by means of funnels deliver the rain into receivers set under the stand on which they are placed.

The Evaporation Gauge differs from that for rain in having within it an upright ½ in. tube, of 4½ in. length, connected with the funnel tube. In use, this gauge is filled to the level of the top of this tube and placed at about 1 foot from the Rain Gauge, both being set 3 ft. 6 in. above ground.

With dry weather evaporation causes the water to sink below the level of the top of the tube, and this loss has to be replaced before any water can pass into the receiver. If after a fall of rain a measure be taken of the contents of the receivers of both gauges, the difference will give the amount of water evaporated from the surface of the Evaporation Gauge during the dry days. For a full description of these instruments, see *Symons's British Rainfall*, 1869 *and* 1870.

100. Evaporation Gauge, designed by the late G. Dines.

1893. *Lent by W. H. Dines, B.A.*

In making observation with this gauge, the cylindrical vessel is placed in a large tank of water, so that its temperature may be kept the same as that of a large body of water, and it is set with its edge about half an inch above the surface.

With the cylinder is connected, by a pipe passing through the tank, the rectangular graduated vessel which registers the level of the water in the cylinder, and from the readings taken the evaporation for any period of time can be found. The graduations represent a depth of 0·1 in. of water, but a depth of 0·01 in. can be measured.

An overflow pipe is provided in case of rain. This should lead into the measuring glass of a rain gauge.

As the evaporation diminishes when the water sinks below the

level of the top edge of the cylinder, it is advisable for accurate observations that the high level of the water should be maintained as far as possible.

101. Atmometer or Evaporimeter, for determining the quantity of water evaporating from the surfaces of waters as well as from different sorts of soil.

E. 224.—1877. *Designed by Prof. Prestel, Emden.*

102. Photograph of Registering Evaporimeter, according to the last plan adopted by the inventor, Prof. Ragona.

1877. *Given by the Observatory of the Royal University of Modena.*

103. Apparatus for determining the evaporation from different soils.

1876. *Lent by Sydney B. J. Skertchly, F.G.S.*

The apparatus consists essentially of an evaporimeter composed of two vessels, the innermost of which receives the material to be experimented upon, and the external one supplies water to compensate for evaporation. Over this is a glass vessel which receives the vapour given off by the material. The temperature, &c., are registered by a hygrometer and barometer in the glass receiver, and the temperature of the soil by a ground thermometer. Any given temperature can be obtained by means of a platinum spiral heated by a galvanic battery. The evaporimeter maintains the material in a natural condition so far as regards temperature and moisture. Dry air is admitted into the glass receiver, and the air with the evaporated water passes from the top of the receiver into a train of drying tubes; the current of air is produced by an aspirator containing oil. By means of this apparatus various soils, &c., can be brought under similar conditions of temperature, &c., and the evaporations compared for any temperature. The apparatus was especially designed to determine the proper amount of water which should be discharged by the artificial drainage system of the Fen Land.

104. Pickering's Evaporimeter.

1896. *Lent by L. Casella.*

The surface from which evaporation takes place is a piece of blotting paper 100 mm. long by 50 mm. wide, which is set in a frame above a small copper cylinder containing water. To keep

this paper moist there is connected with it a narrow strip of the same material, which dips into the water.

The amount of evaporation is read from a glass gauge at the side of the cylinder, which is graduated to directly express by a number of cubic centimetres or cubic inches the evaporation from each square centimetre or square inch of surface.

Full particulars and instructions for use are issued with each instrument.

F.—Anemometers.

105. Drawing and description of D'Ons en Bray's Registering Anemometer, invented in the year 1734.

1892. *Lent by R. B. Prosser.*

This instrument is described in the Mémoires de l'Académie des Sciences, Paris, for 1734. The plate exhibited is a reproduction of one contained in the Mémoires.

106. Photograph of an Anemometer, made by Niccolo Cacciatore in 1832.

1877. *Given by Prof. G. Cacciatore, Director of the Royal University, Palermo.*

107. Whewell's Self-registering Anemometer.

1893. *Lent by the Astronomer Royal.*

At the top of a case containing an upright cylinder marked for the points of the compass is placed a horizontal circular plate to which is attached a wind-vane and a fly of eight fans. Connected to this plate, but contained in the case, is a vertical screw of some 15 inches length, which is set parallel to the cylinder and carries a nut to which is fastened a pencil. As the horizontal circular plate, by the action of the vane, turns with the wind, the pencil is carried round the cylinder, and the direction of the wind shown from the position of the pencil trace with regard to the compass points.

In addition to being carried round, the pencil descends. For the fly revolved by the wind, turns the vertical screw through the action of the intervening wheelwork, and the pencil carrier is lowered. The time being known during which the wind had been blowing in any particular direction, the velocity of the wind could be ascertained from the length of the trace made by the pencil in its descent.

This instrument was used at Greenwich Observatory from 1843 till superseded by Robinson's Cup Anemometer in 1862.

For further information see *Knight's English Cyclopædia, Science Library, Victoria and Albert Museum.*

108. Robinson's Cup Anemometer for registering the velocity of the wind. Graduated in miles and tenths to 505 miles.

1893. *Lent by L. Casella.*

The rotation imparted to the cups by the wind is transmitted by a vertical rod to a horizontal spindle furnished with an endless screw which gears with two worm wheels set together behind the dial. With the front wheel, which has 100 teeth, the dial revolves; with the hind wheel, which has 101 teeth, the long index hand turns.

The dial is graduated on its inner circle for 1 to 5 miles, and a reading is taken by the short stationary pointer above it. The outer circle has 101 divisions to represent each 5 miles to 505, the long hand serving as index.

This latter indication results from the different rates of revolution of the two wheels. The dial wheel with its 100 teeth and the index wheel of 101 teeth move in a direction the reverse of the graduations. On each complete revolution of the former, the latter falls one tooth behind, consequently the hand which moves with it falls one space behind on the dial and thus is apparently advanced one graduation. In this way the 5 miles shown by a complete revolution of the dial are recorded.

109. Anemometer, with Robinson's Cups. Graduated in miles and tenths to 500 miles.

1876. *Lent by F. Darton & Co.*

This is similar in principle to No. 108, but differs in the number of teeth of the recording wheels.

110. Windmill Vane with electrical arrangement whereby the direction of the wind at any instant may be known by sound, constructed for stations of the 2nd and 3rd order in connexion with the Meteorological Office of the Dominion of Canada.

1876. *Lent by G. T. Kingston, M.A., Toronto, Canada.*

This instrument is designed to meet the case when a vane, if suitably exposed, is too distant to admit of being connected by a shaft with a dial in an accessible position.

Surrounding the step of the vane and attached to the bottom of the box is a flat brass ring divided by radial lines into four equal parts corresponding to, but not necessarily in the direction of, the four cardinal points, and separated by small equal intervals.

The direction arcs (as they may be termed) are insulated except as regards connexion with their screw cups.

Clamped to the spindle, and capable of adjustment in azimuth,

is a circuit maker, which consists of an arm bearing a brass arc, which is made to press on the flat brass ring. The length of this arc is 45° + interval between the fixed arcs. The step of the vane is connected by wire with one pole of a battery, and the direction arcs with four screw cups in near proximity to a brass plate fastened to the wall of the office, and so contrived that, by aid of a plug, metallic connexion may be made at will between the brass plate and any one of the four wires.

Finally, two wires from the poles of a small telegraph sounder are attached to the brass plate and to the other pole of the battery, and the apparatus is complete.

To ascertain the direction of the wind, notice by the sounder which direction arcs or pair of arcs is placed in circuit as the brass plate is connected by the plug with the four wires in succession.

If, for instance, N. only sounds, the direction is nearer to N. than either to N.W. or N.E., unless it be N.N.W. or N.N.E. exactly, but if N. and E. *both* sound the direction is nearer to N.E. than either to N. or E., unless it be N.N.E. or E.N.E. exactly.

The azimuth of the vane box need be governed only by appearance and the position of the door.

To adjust the vane, unclamp the circuit maker, and insert a pin (provided for the purpose) through holes at the middle point of the circuit maker and the arc at the left of the box, which arc may represent any one of the four cardinal points. Turn the vane to that point, clamp the circuit maker, and remove the pin, when the adjustment will be complete.

The apparatus works well with a single gravity cell, when the vane is 60 ft. or more from the battery and sounder. With a stronger battery it works well at the distance of a mile or more.

111. Anemometer, with shaft whose length can be adjusted to suit different stations, and with dial reading to 10,000 miles, constructed for stations of the 2nd and 3rd order connected with the Canadian Meteorological service.

1876. *Lent by G. T. Kingston, M.A., Toronto, Canada.*

This instrument is designed to reconcile adequate exposure of the hemispheres with accessibility of the dial.

A short spindle bearing a small set of Robinson's cups is connected with a horizontal cogged wheel resting on friction rollers, and with a long shaft suspended from its centre, as in the anemographs of the British observatories. It is contrived so that the shaft may make 101 complete turns for 200 miles of wind.

The mode of recording the miles is as follows :—

At the lower end of the shaft is an endless screw which acts on the circumferences of two toothed wheels of equal diameter,

turning in vertical planes about a common axis, and having 100 and 101 teeth respectively.

From the centre of the *back* wheel (that of 100 teeth) projects forwards a short hollow pin which incloses and works on a solid pin fixed to a support behind the back wheel.

The *front* wheel (that of 101 teeth) which turns on the abovenamed hollow pin, and slides closely on the face of the back wheel, has a graduated ring on its face, containing 100 divisions. The *outer* ends of the lines of graduation indicate miles, while the *inner* ends of the same lines, reckoned in the reverse order, indicate hundreds.

The endless screw, at every turn, causes both wheels to advance *two* teeth, so that for 100 miles the front wheel makes one complete turn, or 100 divisions, while the back wheel makes one complete turn and one tooth, and thus advances one division with respect to the front wheel. The miles up to 100 are shown by a fixed pointer, and the hundreds by a pointer attached to the end of the hollow pin.

For fractions of a mile there is a contrivance which needs adjustment at each observation.

A correction of 1 per cent. nearly should be subtracted from the fractional parts.

112. Galton's Hand Anemometer.

1894. *Lent by the Meteorological Council.*

This is a small portable arrangement of Robinson's cups with a dial which reads to 45 miles an hour. Attached to the frame of the instrument is a sand glass which empties in two minutes. The sand glass is connected at the back of this frame with the dial, so that, on its being turned to allow the sand to run out, the dial is put in gear with the screw of the spindle of the cups, but on reversal of the glass is thrown out of gear.

In this way the velocity of the wind as indicated by a short period of exposure is registered.

This instrument was designed for the use of seamen in order that the records kept in log books of the force of the wind might be obtained by a uniform method of observation.

113. Lind's Water Anemometer, for indicating the pressure of the wind.

1876. *Lent by F. Darton & Co.*

For observations the tube is filled with water until its level reaches the zero mark on the scale. If it then be brought into position with the mouth of the longer branch facing the wind the water will rise in the shorter branch to an extent which will vary with the wind's force.

From the difference of levels, with the aid of scales prepared

for each instrument, the pressure and also the velocity of the wind can be ascertained.

The wind vane serves to turn the mouth of the tube to the wind, and also indicates direction.

Oscillations owing to rapid changes of pressure are lessened by narrowing the tube connecting the two branches.

114. Lind's Anemometer, as modified by Sir W. Snow Harris.

1894. *Lent by the Meteorological Council.*

In this modification a longer range is obtained by setting part of the registering branch of the tube in a horizontal position and narrowing its bore.

Sir W. Snow Harris also furnished his instruments with a plummet or other means of setting them in a vertical position.

115. Portable Anemometer, designed by W. H. Dines. Adapted for use at sea.

1896. *Lent by L. Casella.*

In observations the tube is drawn from its case, and, using the latter as a handle, held in a vertical position with the nozzle as nearly as possible facing the wind. The height to which the liquid rises in the tube then indicates by the scales the velocity of the wind in miles per hour and its pressure in lbs. on a square foot.

Instructions for observers are issued with each instrument.

116. Balance Anemometer constructed by Mr. Francis Ronalds at the Kew Observatory, in 1843, for the purpose of measuring the force of the wind.

1876. *Lent by the Kew Committee of the Royal Society.*

It consists of a light board, 1 foot square, fixed transversely to a cross of wood, suspended by a brass axis passing through its centre, and turning in glass tubes in such a way that the system can partially rotate in a vertical plane. The lower end of the bar carrying the board is counterpoised, so as to keep the surface of the board vertical, and a scale pan, hung to one end of the horizontal bar of the cross, serves to receive the weights, which are necessary to counterbalance the force of the wind pressing on the board opposed to it, at any time. A small box, covering the scale pan, serves to shield it from the action of the wind. The instrument was, at the time of observation, placed so that the surface of the pressure plate should stand at right angles with the direction of the wind, as indicated by a vane.

117. Dynamic Anemometer for obtaining the horizontal and vertical pressure of air in motion upon inclined surfaces of different forms and angles. Manufactured by John Browning.

1876. *Lent by the Council of the Aeronautical Society of Great Britain.*

This instrument is intended simultaneously to determine the component parts—*i.e.*, how much pressure is due to the horizontal, and how much to the vertical—of a current of air when directed against planes of different areas, and of different forms, at angles varying from 15° to 90°. The experiments are tabulated in the *Aeronautical Society's Report for the year* 1871 (*Hamilton & Co.*).

118. Apparatus, designed by W. H. Dines, for determining the pressure of the wind on inclined surfaces.

1898. *Lent by W. H. Dines, B.A.*

This arrangement was constructed with a view to its being revolved by some form of whirling machine; and the results obtained by a number of experiments with it, when connected to the 56 feet diameter apparatus at Hersham, have been published in the Proceedings of the Royal Society for 1891.

When carried round by the machine the pressure of the air is balanced by the centrifugal force upon the two horizontal bars. Of these the larger is adjusted by hand and clamped, but the final adjustment is effected by the automatic action of the smaller bar.

The pressure board is inclinable, and the lever which carries it can be set at any angle with the help of the graduated arc, to which, when used for observations, it is clamped. This arc is connected by an arm and stud with the pivoted frame carrying the two horizontal bars in such a way that the movement in a vertical plane of the lever produces a movement in a horizontal plane of the bars. This allows a pulley to act through a crown wheel, pinion and rack on the smaller bar, which is carried along until equilibrium is established between the wind pressure and the centrifugal force. The pressure is then determined from the positions of the bars, as shown by their graduations.

119. Shot Wind-pressure Gauge.

1893. *Lent by W. H. Dines, B.A.*

This instrument measures the maximum wind pressure. The upper receptacle is filled with shot, which fall through the hole at the bottom, until the weight of the shot in the lower vessel is equal to the pressure of the wind on the plate.

As soon as this occurs, the plate moves forward, and at the

same time closes the opening. On the occurrence of a stronger gust of wind, the plate is forced back, the hole is opened, and shot fall through until equilibrium is again obtained.

To read the instrument, the plate is fastened in its forward position by the catch on the upper receptacle, and the shot are then withdrawn from the lower receptacle and weighed, or, preferably, measured in a glass which has been tabulated once for all. The weight of shot gives the maximum pressure which has occurred since the instrument was last set.

120. Apparatus used for determining the distribution of wind-pressure upon flat surfaces exposed perpendicularly to the wind.

1893. *Designed and lent by R. H. Curtis, F.R.M.S.*

The object of these experiments was to investigate the distribution of wind-pressure over flat surfaces of different areas exposed perpendicularly to the wind.

The plates used for the purpose were pierced with holes half an inch in diameter, and situate at known distances from the centre, where there was a similar hole called the "standard."

In making an observation all the holes except the "standard" and one other—which was the hole to be compared with the standard—were closed by means of plugs, inserted from the back, and fitting flush with the front surface of the board, so as to make it continuous. Into the two open holes brass nozzles were then inserted from the back; and these were connected by india-rubber tubes with two graduated glass tubes standing vertically in a glass jar containing water.

The face of the board being presented to a current of air a depression of the water was caused in the glass tubes; and the observation was made by noting the amount of this depression in the two tubes at the same moment.

Experiments were made with square surfaces of 1, 1·2, 6·25 and 16·0 sq. ft. area respectively, and with a circular surface of 2 sq. ft. area.

From the mean results obtained, the distribution of pressure over the surface was determined; and it is shown graphically by means of lines drawn upon diagrams representing the surface experimented upon.

[For further particulars see the *Quarterly Journal of the Royal Meteorological Society, Vols. VIII. and IX.*]

121. Howlett's Anemograph for registering the direction and force of the wind.

1893. *Lent by Elliott Bros.*

The sphere to receive the wind pressure and the pencil to record it are connected by a brass rod, which acts as a lever

having as fulcrum the gimbal support at the top of the case of the recording slate.

According as light or heavy pressures have to be measured, the sphere is raised or lowered on the rod, and its position and that of the weight on the recording end of the rod serve with the trace in determining the force of the wind in lbs. per square foot.

These instruments are constructed so that when the sphere is in its lowest position 0 to 20 lbs. pressures can be shewn, when at its highest 0 to 5 lbs. and with the small weight at the top 0 to 2½ lbs.

The circle of the recording slate is divided from 0° to 360° by 5° intervals, and the direction of the wind and the value of the pressure are ascertained from the position and length of the pencil trace. Specially constructed scales are issued for use with each instrument.

122. "Self-recording Wind Components Integrator." Constructed by P. Schultze, designed by Dr. Arthur Von Oettingen, Professor at the Imperial University, Dorpat (Russia).

1880. *Lent by the late W. Spottiswoode, F.R.S., and the late Warren de la Rue, F.R.S.*

The wind moves a system of hemispherical cups, like Robinson's (which motion is replaced by clockwork for exhibition), acting on a circular plate, whose velocity is ordinarily proportional to the velocity of the wind. Four systems of sliding-rollers rest on this plate, whose bearings can be moved round a vertical axis, the principal planes of which imitate all variations of a wind vane. Each sliding-roller can rotate about a horizontal axis, but only in one direction, and after a half rotation an electrical contact is made. A mechanism limits the contact to a fraction of a second. When the contact is made, one of four wheels, with number-types, is moved. Every half hour the position of these four wheels is shown by printed numbers on a strip of paper. The differences of those readings represent the mean velocity of the wind from N., E., S., and W. They are converted into absolute values by means of a table. Different mechanism adjusts the position of each sliding-roller.

123. Integrating Anemometer. Designed by Walter Bailey, M.A., F.R.S.

1889. *Lent by the Govt. Grant Committee, Roy. Soc.*

This is somewhat similar to the Integrating Anemometer of Dr. A. von Oettingen, the records being obtained from wheels revolved by the friction of a plate turned by the wind.

There are two spindles, one to support the Robinson cups, and transmit their movement to the circular plate on which

the recording wheels rest, the other for the vane to change the position on the plate of the two recording wheels in accordance with the direction of the wind. That this change may be readily effected, the wheels are connected to small carriages which run between tram lines on a plate placed parallel to, and above that which revolves.

By the method of connection with the direction spindle, one wheel turns when the wind is at either of the four chief points of the compass; in intermediate directions, as N.E., S.S.W., both are turned.

As the speed of the revolving plate is ordinarily proportional to that of the wind, a measure can be obtained of the velocity of the latter from the number of revolutions of the wheels. The recording is effected by an electrical contact made at each turn of the wheels, which allows a current to actuate a set of counters.

These counters are contained in a box, and are connected with the instrument by wires to the binding screws which represent the N., S., E., and W. points.

The value of the records can be determined either by measurement of the instrument or by direct experiment.

For a full description of this anemometer see *Philosophical Magazine, June, 1884.*

124. Photograph of an Anemograph with Rain Gauge annexed. A description of the instrument is shown with the photograph.

1877. *Given by Prof. Palmieri, Vesuvian Meteorological Observatory, Naples.*

125. Anemometer consisting of inclined vanes, contained in circular brass band, with registering apparatus. Used in regulating the ventilation of mines. Diameter $2\frac{1}{2}$ in.

1875. *Lent by Pastorelli & Co.*

126. Anemometer. Consists of a series of inclined vanes with a registering apparatus in a brass circular band. Used in mine ventilation. Diameter 6 in.

1876. *Lent by F. Darton & Co.*

127. Self-timing Anemometer.

1893. *Lent by Messrs. Davis & Son, Derby.*

By this instrument the use of a watch in ascertaining the velocity of the air is dispensed with.

In taking observations, the anemometer is exposed for a few seconds with its back to the current, and the spring plunger

pushed in; the position taken up by the index then shows the velocity in feet per second of the air. When more than one revolution of the index has been made the inner circle of figures must be read.

The screw with milled head is used to release the plunger and bring back the index to zero.

G.—Ozonometers.

128. Smyth's Ozonometer, made of brass, lined with sealing wax, and provided with brass stop-cocks. Invented by contributor previous to ozonometer No. 132.

1876. *Lent by John Smyth, jun.*

In this and succeeding instruments the amount of ozone present is judged by its action on a test paper contained in the box. These papers are prepared in various ways, the substance used by Schönbein being iodide of starch.

The papers after exposure for a definite time are taken out and compared with some standard tints forming a scale.

129. Smyth's Ozonometer, made of brass, lined with glass, and provided with glass stopper to admit air. Invented by contributor previous to ozonometers Nos 128 and 132.

1876. *Lent by John Smyth, jun.*

130. Diagram showing the rough form of ozonometer and aspirator used by contributor in his first experiments, August 1865.

1876. *Lent by John Smyth, jun.*

131. Diagram showing the contributor's ozonometer connected to Dr. Andrew's form of aspirator by means of which his later experiments have been made.

1876. *Lent by John Smyth, jun.*

132. Smyth's Ozonometer, for the determination of the amount of ozone in a measured volume of air by means of an aspirator. Invented by the contributor and

described by him in a paper read at the meeting of the British Association in Birmingham in 1865.

1876. *Lent by John Smyth, jun.*

It consists of a boxwood tube or cylindrical box, about 2 inches long and 2 inches in diameter, one end of which is closed, except in the centre, where it is pierced by a quarter-inch tube communicating with the aspirator; the open end is covered by a lid or second box of the same material, which is so large as to slide over the first, and is also pierced by a quarter-inch tube, which, when the ozonometer is arranged for an experiment, directs the air against the centre of the test paper stretched across the open end of the inner or first box, and secured there by an india-rubber band lying in a groove.

H.—Miscellaneous Meteorological Apparatus.

133. Instruments issued by the Meteorological Council on loan for the use of observers.

1893. *Lent by the Meteorological Council.*

Barometer, Negretti and Zambra. Similar to barometers lent to small ports and fishing stations.

Specimens of Instruments, lent to observers for use at sea:—

Barometer, "Adie."
Thermometers. Dry and wet bulb. In a screen.
Water Thermometer.
Hydrometer. Casella.

Additional Instruments for use at Telegraphic Reporting Stations:—

Thermometer, Maximum.
——— Minimum.
Rain Gauge, with collecting can and measuring glass.

134. Photographs of Padre Secchi's Meteorograph and the curves traced by the instrument. A printed description is shown with the photograph.

1877. *Given by the Observatory of the Collegio Romano. Director, Padre Secchi.*

135. Photographs of Meterological Instruments exhibited in the Loan Collection of Scientific Apparatus, 1876.

Kreil's Barograph.
Milne's Barograph.
Ronald's Photo-Barometrograph.
Diagonal Barometer. Date about 1750.
Mercurial Barometer by Reballio.
Two Barometers formerly belonging, the one to Lavoisier, the other to H. B. de Saussure.
Barometers by Dr. Wild, W. Gloukhoff and Dr. A. Krueger.
Observatory Standard Barometer by Casella.
Negretti and Zambra's Self-registering Mercurial Barometer.
Bourdon's Balance Barometer and a Goldschmid's Aneroid.
Window Stand and Screen used at German Naval Observatories.
Thermometers and Screens used at Norwegian Meteorological Stations.
Hygrometer of early form. (This apparatus is at King's College Museum.)
Hair Hygrometers by H. B. de Saussure.
Richer's 8-hair Hygrometer and two single-hair Hygrometers.
Anemometer with electrical registration. Made by Yeates and Son.
Anemometer with electrical registration. Made by Pastorelli.
Lind's Anemometer as modified by Sir W. Snow Harris.

136. Meteorological Table, arranged by the late Bennet Woodcroft from data kept by Mr. Glaisher.

The observations of the thermometer and barometer extend over a period of 80 years, those of the rain gauge over 39 years.

137. Hypsometer. An instrument for determining altitudes by observations of the boiling point of water.

1893. *Lent by L. Casella.*

It consists of a cylindrical chamber for water, connected to a tube along which the steam that has been generated makes its way to the outer air. In this tube, which is protected from cold by an outer casing, is placed a thermometer with its bulb supported a short distance above the level of the water.

The heating is by a spirit lamp screened from the wind by a tin box.

Altitudes are ascertained by means of specially prepared tables in which the heights corresponding to a particular temperature of the boiling point are given, also the corrections to be made for variation in mean temperature and for other sources of error.

The outer casing is made to telescope, and the whole apparatus constructed with a view to portability.

138. Cloud Mirror. Designed to ascertain the direction from which the clouds are moving.

E. 2.—1863. *Given by J. T. Goddard, from Exhibition of* 1862.

For observations, the mirror is laid on a horizontal support near a window and set so that the point marked north is directed to the south point of the horizon; the several points will then be reversed. The edge of a conspicuous cloud is brought to the centre of the mirror and the point of the compass noted where it passes off the margin. This gives the point from which the clouds are coming.

139. Apparatus to illustrate the formation of Tornado Clouds.

1897. *Designed by W. H. Dines, B.A.*

The apparatus for this experiment, as made by Mr. Dines, is of a simple and inexpensive form; that shown is of a somewhat more substantial character, to adapt it for exhibition.

Three glass plates, 18 inches by 24 inches, are set in each of two frames, so as to form when put together a hollow hexagonal prism. These frames are placed upon a table with their edges apart and slightly overlapping, to allow of the entry of air obliquely. A board, with a hole in its centre, in which is set a fan that can be rotated by a pair of pulleys, forms a cover to the prism, and a shallow copper evaporating pan and a burner complete the essential parts of the apparatus.

If, when sufficient steam is generated from the water in the pan, the fan is rotated, a column will be produced in many respects similar to that of a Tornado Cloud.

The points of resemblance to the actual tornado cloud formation are stated by Mr. Dines to be:—

1. A distinct rotary motion round the centre, increasing in violence towards the centre.
2. A strong up-draft.
3. A decrease of pressure in the centre of the column.
4. The hollowness of the column.

See *Journal of the Royal Meteorological Society, January,* 1896. *Science Library, Victoria and Albert Museum.*

140. Portion of a Conductor fused by lightning at Caterham.

1893. *Lent by the Lightning Rod Conference, per the late G. J. Symons, F.R.S.*

The bright spots near the rivet and the end of the screw shew fusion.

141. Inefficient Lightning Conductor. Removed from the Royal Hospital for Incurables, Putney.

1893. *Lent by the Lightning Rod Conference, per the late G. J. Symons, F.R.S.*

142. Spratt's Patent Lightning Conductor, 12 wires (No. 15, B.W.G.), 2 wires (No. 18, B.W.G.). Weight, 3·3 ozs. per foot.

1893. *Lent by the Lightning Rod Conference, per the late G. J. Symons, F.R.S.*

143. Portions of a Rafter shattered by lightning at Kentish Town.

1893. *Lent by the late G. J. Symons, F.R.S.*

144. Rhé Electrometer of Marianini, for observing electric discharges between the atmosphere and the earth.

1876. *Lent by the late Robert James Mann, M.D.*

This instrument was planned by Professor Melsens. It contains a coil of copper wire which is to be made continuous with the system of a lightning rod, or with the earth wire of a telegraph line. When an electric current passes through the coil a soft iron bar in its interior is magnetised, and a traversing magnetic needle pivoted above the coil is deflected out of the north and south line of the earth's magnetism towards either the east or west. When the interior iron has been magnetised it must be replaced by a neutral bar before another observation can be made.

145. Photograph of a Bifilar Electrometer and apparatus with movable conductor. With printed descriptions.

1877. *Given by Prof. Luigi Palmieri, Vesuvian and Meteorological Observatory, Naples.*

146. Sky Sketches, a series of 533 in 72 frames, taken between September, 1883, and September, 1886.

1888. *Drawn and lent by W. Ascroft.*

These sketches illustrate optical phenomena attributed to the eruption at Krakatoa in the Java Straits, August 27, 1883.

147. The Chromatics of the Sky. A selection of 18 coloured drawings taken in latitude 51° 31′ 15″ N. and longitude 0° 9′ 45″ W., at 135 feet above sea level.

1889. *Lent by J. S. Dyason, F.R.G.S., F.R.Met.Soc.*

These are taken from a series of about 300 drawn by the exhibitor.

I.—Terrestrial Magnetism.

148. Photograph of an Inclinatorium (Dipping Needle), by Daniel Bernoulli, made by Johann Dietrich, of Basle, in 1751.

1877. *Given by Professor Hagenbach-Bischoff, Director, The Physical Institute in the Bernoullianum, Basle.*

This instrument gained the prize of the Academy of Paris in 1743.

149. Dip Circle for observations at sea, fitted with special arrangements for finding the magnetic meridian. By Nairne and Blunt; date, 1772–1834.

1876. *Lent by the Hydrographic Department of the Admiralty.*

This instrument may be considered as intermediate in construction between that made by Nairne for Captain Phipps, in his voyage towards the North Pole in 1773, and the Fox circle introduced by Mr. R. W. Fox in 1834.

It is suspended by an universal joint from a wooden stand carrying one adjusting screw. The needle, 9 in. long, with steel axles, vibrates within a circle graduated to 20′, and the ends of the axis are fitted to work in the agate holes of two adjustable screws in the vertical bars supporting the circle, and otherwise strengthening the instrument. The sliding pointers on the graduated circle are intended to be adjusted to the mean position of the needle when the motion of the vessel causes it to vibrate on either side of the dip. The screw on the under side of the circle works the metal supports on which the needle is placed until adjusted in the agate holes. A thermometer graduated to –38° is placed inside the instrument.

The peculiar arrangement for ascertaining the magnetic meridian consists of a small compass gimballed at the end of a wooden arm. The other end of this arm has a brass fitting to fix on pins in the graduated circle on the top of the frame. The motion of the arm in azimuth causes the whole apparatus to move in the wooden stand until the dip circle is in the magnetic meridian, as indicated by the compass.

150. Dip Circle and Intensity Apparatus. Fitted with arrangements for ascertaining the magnetic meridian by three methods. By Dollond; probable date, 1776–1834.

1876. *Lent by the Hydrographic Department of the Admiralty.*

The dip circle is made after the pattern described by the Hon. Henry Cavendish in the Phil. Trans., vol. xlvi., in which the dipping needle rolls upon horizontal agate planes, and a contrivance is applied for lifting it off and on to the agates at pleasure. A milled-headed screw works this lift, and an adjacent butterfly screw, an arrangement for causing the needle to vibrate. The vertical circle is graduated to 20′; the outer circle of the base plate is also graduated to every 45°.

The direction of the magnetic meridian may be ascertained by two methods other than that usually adopted:—1. An edge bar horizontal needle fitted with an agate cup may be placed on the steel point fixed to a balanced axis provided for placing on the agates like the dipping needles. The coincidence of this needle with the plane of the vertical circle shows the latter to be in the magnetic meridian. 2. The same edge bar needle can be placed on a pivot screwed in the centre of the graduated circle at the bottom of the travelling box.

Of the three dipping needles, two are flat and one cylindrical and sharply pointed. The axes are made of gun metal, and one of the flat needles is fitted with a brass cone on Mayer's principle.

Intensity Observations.—For this purpose the box which carries the dip circle is fitted with two apertures filled with glass, and a torsion circle on the top. The two flat needles, one of gun metal for eliminating torsion, and the other for horizontal vibrations, have metal pins screwed into the centres by means of which they are attached to the stirrup suspended by silk fibres from the torsion circle. The vibrations are observed through the glass sides, and the magnetic meridian by the edge bar horizontal needle before described.

This apparatus closely resembles that used by David Douglas on the north-west coast of America and the Sandwich Islands in 1829–34.

151. Dip Circle. By Robinson.

E. 13.—1900. *Bequeathed by W. Tucker Radford, M.B.*

This is a similar instrument to those described under Nos. 152 and 153. Four 6-inch needles are supplied, and also a horizontal edge bar needle with pointed support for finding the magnetic meridian after a manner described in No. 150.

152. Dip Circle. By Robinson; date, 1830–75.

1876. *Lent by the Hydrographic Department of the Admiralty.*

In this circle the needles are 6 in. long, flat, and pointed. They move on agate planes in the centre of a graduated circle, and observations are read off by means of lenses fixed in the ends of a movable arm centred on one of the glass sides of the instrument.

The advantages of this form of dip circle are:—1. That the needles can be read off for nearly every angle of dip. 2. Portability, from compactness of stowage in the box, as the vertical circle is fitted so as to be readily detached from the horizontal.

An instrument of this kind was used by Major Estcourt during the survey of the River Euphrates in 1836.

153. Dip Circle used by Sir James C. Ross.

1876. *Lent by the Kew Committee of the Royal Society.*

A Robinson dip circle with 6-inch needles, supported on agate planes, and read off direct on the circle of the instrument. Similar to Nos. 151 and 152.

154. Dip Circle.

E. 18.—1889. *Made by A. Dover.*

This instrument is of the type usually found in magnetic observatories, and was employed during the recent magnetic survey of the United Kingdom.

155. Dip Circle, similar to that used by M. Moureaux in the magnetic survey of France, 1884–5.

E. 26.—1889. *Made by Brunner Frères, Paris.*

The dimensions of this instrument are considerably less than those of the English form, but the principle is the same in both. The circle reads to 1′.

156. Drawing of a Dip Circle.

1876. *Lent by the late J. P. Joule, F.R.S.*

The needle, constructed of a thin ribbon of annealed steel, weighing 20 grains, is furnished with an axis made of a wire of standard gold. This axis is supported by threads of the Diadema Spider attached to the arms of a balance suspended by a fine stretched wire. The whole is hung by a wire which can be twisted at the head through 180°. At the bottom is attached a paddle immersed in castor oil, which brings the instrument speedily to rest in a fresh position. The deflections are read off

by a short-focus telescope, placed on an arm revolving on an axis in the centre of the circle. With this instrument the dip can be determined within the fraction of a minute of arc in less than a quarter of an hour.

With this drawing is exhibited a specimen of the thread of the Diadema Spider, also thread of the Diadema Spider Cocoon.

157. Dipping Needle Instrument, designed by W. T. Goolden, M.A.

1893. *Lent by L. Casella.*

A 3½-inch needle, provided with adjustable counterpoises contrived so as to bring the centre of gravity very accurately into the axis of support, is carried in jewelled centres on a horizontal axis. The inclination of the needle to the horizon is read upon a metal circle, graduated in degrees on both sides, and the whole is enclosed in an air-tight box with glass faces, revolving about a vertical axis. In order to facilitate the adjustment of the needle to the magnetic meridian, the vertical axis of the instrument is furnished with a spring arm, which can be clamped to it, and there are four metal studs on the stand at right angles to each other, into which the head of the spring arm fits when pressed down with the finger.

The instrument is similar to those occasionally lent by the Department to Science Classes.

158. Hansteen's Intensity Apparatus, used by Capt. Barnett, in H.M.S. "Thunder," in 1841.

1876. *Lent by the Kew Committee of the Royal Society, Kew Observatory.*

Consists of a glazed box 4 in. square, standing on a levelling stand and carrying a brass suspension tube 6 in. in length. It also has an ivory circle fixed to its bottom.

There are two magnets 2·7 in. long, each of which when not in use is kept in a separate little copper box, where, fitted to an armature, it is embedded in iron filings.

159. Hansteen's Intensity Apparatus; date, 1819–50.

1876. *Lent by the Hydrographic Department of the Admiralty.*

This form of intensity apparatus is that first adopted by M. Hansteen in his magnetic survey of Norway and the Baltic shores in 1819–24, and since largely used by various observers. The vibrating needle is cylindrical, pointed at the ends, 2·65 in. long and 0·15 in. in thickness. It is suspended from the movable pulley at the end of the brass tube by a fibre of

silk secured to a brass strap and loop in its centre. By means of the pulley the needle can be adjusted to the required height in the vibrating box.

The value of the observations depends on the permanency of the magnetic condition of the needle.

160. Magnetometer, Kew pattern.

E. 40.—1889. *Made by Elliott Bros*

This magnetometer is intended for use either in the observatory, the laboratory. or the field, for the determination (*a*) of the magnetic declination, (*b*) of the horizontal component of the earth's magnetic force, commonly denoted by H.

In finding the magnetic declination two distinct determinations have to be made:—First, that of the direction of true or geographical north by means of sun observations; secondly, that of the direction of magnetic north by means of a properly suspended magnet.

The Kew magnetometer consists essentially of a divided circle, supported on three levelling-screws, by which it can be made horizontal, and a second circle, concentric with the first, which can turn about a vertical axis through their common centre. The second circle carries two verniers and reading microscopes at opposite ends of a diameter, by means of which its position with regard to the first, or lower circle, can be read to 20″ of arc. It carries also, at opposite ends of a diameter, a horizontal telescope with cross wires in the eye-piece, and a small square mirror which is capable of turning round a horizontal axis, and of which the supports are carried by a circular table which may be rotated and clamped in any position, so that the plane of the mirror is adjustable in any required way. There are also various other small adjustments by means of which the axis of the mirror may be made horizontal and perpendicular to the line of collimation of the telescope, and the plane of the mirror made parallel to its own axis of rotation.

As the proper adjustment of the mirror is a matter of importance, the telescope is specially constructed to give a convenient method of adjusting it in the field. For this purpose the brass tube of the telescope is cut away near the eye-piece, and replaced by a short length of glass, within which a piece of polished platinum, forming the end of the tube which carries the eye-piece, is placed at an angle of 45° to the optic axis.

This platinum reflector is pierced by a hole so that it does not form an opaque stop across the telescope, but sufficient reflecting surface is left for a good light to be thrown on the cross wires when it is turned to a bright part of the sky; then the mirror at the opposite side of the instrument is rotated, until the image of the illuminated cross wires formed by reflection from it is seen to coincide with the cross wires themselves. When this is the case the mirror is correctly adjusted. To cut off external light

from the object glass during this adjustment, a small blackened screen is fixed to the stand behind the mirror, and a blackened tube placed between the mirror and the telescope, of such length that the object glass just enters within it.

In making sun observations, the whole of the upper part of the instrument is rotated, and the mirror tilted at a proper angle, until an image of the sun is seen by reflection from it in the field of view of the telescope.

Dark glasses of two shades are carried either in the eye-piece or just in front of the object glass to reduce the brightness of the image, if necessary.

The observer, by means of a chronometer ticking half seconds, notes the exact times at which the two edges of the sun's disc touch the vertical cross wire as the image moves across the field of view, reading also by means of the verniers the position of the upper circle with regard to the lower graduated one. These observations properly worked out will give the reading on the circle corresponding to the direction of true north.

The second part of the observation consists in suspending a specially constructed magnet, and determining by its means the magnetic meridian,

The magnet used for this purpose is a hollow cylindrical bar of steel, closed at one end by a lens, and at the other by a piece of plane glass on which a tiny scale is photographed. This is suspended by a silk thread about a foot long and hangs, within a wooden box (to exclude draughts) with glass windows, on a level with the telescope.

The thread is fastened at its upper end to a torsion head at the top of a stout glass tube; the lower end of the tube screws into the wooden box, and the wooden box is screwed on at the centre of the instrument, between the telescope and the mirror, after the sun observations have been made. Diffused light may be reflected either from the mirror or a piece of white paper, right through the hollow magnet, so that the scale on its plane glass end is clearly visible through the telescope. The magnet is allowed to swing freely, and the upper part of the instrument again rotated until the central division of the scale is seen to coincide with the vertical cross wire in the eye-piece. The position of the upper circle with regard to the lower is again read by means of the verniers, this reading corresponding to the direction of magnetic north. The difference between the two readings thus obtained, viz., that corresponding to the geographical, and that to the magnetic meridian, will evidently be the required magnetic declination, which may thus be obtained to within a third of a minute of arc.

To find H, or the horizontal component of the earth's magnetic force, two distinct experiments have as a rule to be made. If a freely suspended magnet is set swinging, its time of vibration depends both on its own strength (or more correctly *magnetic moment*) and on the strength of the magnetic force in its neighbourhood,

If the moment of the magnet were a constant quantity, it could be determined once for all, and then one experiment would be sufficient to find H at any point. But as a magnet cannot be constructed which does not become weaker with time, *two* experiments have to be performed, one of which gives the product and the other the ratio of the two changeable quantities, from which either or both may be found.

In the *vibration* experiment, which gives the product of H and the moment of the magnet, the disposition of the instrument remains exactly the same as in finding the declination; the magnet is set swinging steadily through a small arc, and the time which it takes to make one vibration found by means of the ordinary eye and ear method with the chronometer ticking half-seconds, the experiment lasting until 100 complete swings have been made. A thermometer is placed within the box in which the magnet swings, to give its mean temperature during the observation, this being important from the alteration produced by a change of temperature in the magnetic moment of a magnet.

The second part of the experiment consists in determining the angles which the magnet used in the first part is able to deflect a second magnet from its position of rest in the magnetic meridian, when held at two definite distances, in certain positions, from it. It is obvious that the stronger the first magnet is, the greater will be the deflection of the second produced by it; while the greater the horizontal component of the earth's magnetic force, the less will be the deflection of the second magnet under the influence of any neighbouring magnet. To perform this part of the experiment the wooden box and glass tube used before are removed, and another shorter tube screwed on at the centre of the instrument, protecting the silk fibre by which the second magnet is suspended at a lower level than that at which the declination magnet was hung.

A second telescope, carrying a scale engraved on ivory above the eye-piece, is fastened by screws to the instrument below the telescope already mentioned, which is not used in this part of the experiment, and, as it would be inconvenient to send light *through* the suspended magnet in this case, the scale is seen by reflection from a small mirror which is rigidly attached to it, the arrangement answering just the same purpose as the lens and photographed scale in the first case.

A carefully graduated brass bar, about one metre in length, is now attached horizontally to the circle, so that it passes beneath the centre of the suspended magnet, and is at right angles to the telescope, and on this bar, at certain distances, the first magnet (that is, the one that was suspended during the declination and vibration experiments) is successively placed, supported on a little stand so as to be on a level with the second and perpendicular to it. The instrument is rotated as before until in each case the central division of the scale coincides with the vertical cross wire in the eye-piece of the telescope, and from the angles of rotation

when the deflecting magnet is at different distances, and with its N. and S. poles alternately directed towards the suspended magnet, the required ratio is deduced. A thermometer is hung on the brass bar during the observation, as near as possible to the deflecting magnet, for the same reason as in the case of the vibration experiment.

161. Portable Magnetometer similar to that used by M. Moureaux in the magnetic survey of France, 1884–5.

E. 27.—1889. *Made by Brunner Frères, Paris.*

This instrument differs from the Kew magnetometer No. 160 chiefly in point of dimensions, and in the method by which the sun observations are made. The latter instrument, in its box, weighs about 50 lbs., while the French pattern weighs only about 9 lbs. In an observatory the extra size and weight of the English instrument are of no consequence, and even in the field its extra solidity may sometimes be an advantage, but there is no doubt as a general rule that in outdoor work the much greater portability of the French form is a strong point in its favour.

The main difference in principle between the two instruments is that in the French form the *mirror* (for reflecting the sun) is done away with, and the telescope can rotate in a vertical plane about a horizontal axis, so that it forms an *altazimuth* instrument, and the sun is looked at directly instead of being seen by reflection. By this arrangement an exact knowledge of true time becomes less important than in the other case.

The magnet is a solid cylinder, 6·5 cm. in length, 4 mm. in diameter, and weighing 7½ grammes ; its ends are slightly concave and polished, and serve to form an image of a cross wire in the reading microscopes, which are moved when the declination is being determined until the wire and its image are coincident, thus answering the same purpose as the hollow magnet, scale, and lens of the Kew pattern.

The accuracy attainable in the determination of declination is about the same with the French as with the English instrument, notwithstanding the much smaller dimensions of the former. But in the vibration and deflection experiments less care is taken with regard to the temperature of the magnet, and there is little doubt that " H " is found with a greater degree of accuracy with the English form of instrument than with the French.

162. St. Helena Magnetometers.

(1.) Declinometer and Telescope, used at St. Helena, 1840–1849.

(2.) Bifilar Magnetometer and Telescope, used at St. Helena, 1840–1849.

(3.) Vertical Force Magnetometer, used at St. Helena, 1840–1849.

1876. *Lent by the Kew Committee of the Royal Society.*

The three magnetometers, the declination, horizontal force and vertical force instruments, respectively, were made by Grubb, of Dublin, and formed one set of those used in the Colonial Magnetic Observatories, founded by the Government in 1840. The instruments were described in the Report of the Royal Society Committee of Physics, &c.

These instruments were erected at St. Helena in 1840, and constantly observed from that date until 1849.

The declinometer consists of a magnet bar, suspended by fibres of untwisted silk, and carrying a collimator arrangement of lens and scale, the whole being enclosed in a cylindrical casing, perforated with windows, through which the scale is viewed by means of a telescope.

The bifilar is a somewhat similar arrangement, but the support of the magnet is formed of two parallel wires, which are twisted so as to bring the magnet into a position at right angles to the meridian.

The vertical force magnetometer is a light magnet, 12 in. long, carrying a brass frame with cross wires at each end; it is supported by a steel knife edge, bearing on agate planes, and its movements are observed by microscopes, fitted with micrometers, by which the position of the cross wires on the magnet is read.

163. Declination Compass, used by Sir J. Richardson and Capt. Pullen.

1876. *Lent by the Kew Committee of the Royal Society.*

It consists of a square glazed box, containing a compass card, formed of a light metal divided circle, and two needles, connected to an agate cup in the centre. This card is mounted so that it can either be suspended by a silk thread, or rest upon a point in the ordinary manner.

Two microscopes are fixed vertically above it, so that the divisions on the circle may be read by them, concave metallic reflectors being fitted to them for the purpose of illuminating the scale at the time of reading off.

164. Photographs of a "Compass Theodolite," an instrument invented by the exhibitor, for observing, with a microscope, the exact position of the magnetic needle. In two frames.

1877. *Given by Prof. Joseph Schlesinger, Vienna.*

165. Self-recording Magnetometer.

1876. *Lent by the late Chas. Brooke, F.R.S.*

Rough home made apparatus, by which the first automatic records of magnetic variation by reflected light were obtained. The cylindrical lenses are water-lenses.

166. Self-registering Balanced Magnetometer, with compensation for changes of temperature, and warm water envelope for testing the same. The compensation is effected by the weight of the column of mercury in a thermometer tube.

1876. *Lent by the late Chas. Brooke, F.R.S.*

This instrument can be used with the recording apparatus No. 168, or observations can be made with a telescope.

The magnet is supported by a bar at right angles to it, which rests by knife edges on agate planes. At the other end of this bar are a concave metal reflector and a plane mirror. The former is used for reflecting to the photographic recording apparatus rays of light received from the lamp; the latter, for reading the deviations of the magnet with a telescope in the ordinary way. As any movement of the magnet is necessarily conveyed to the concave mirror, the curve traced by the reflected pencil of light on the revolving recording drum will serve as a record by which the change of inclination of the magnet can be ascertained.

167. Self-registering Syphon Barometer, used in connection with the magnetic recording apparatus.

1876. *Lent by the late Chas. Brooke, F.R.S.*

The registration is effected by a lever bearing at one end a card with a slit and at the other a float which rests on the mercury in the cistern.

The rise or fall of the mercury causes a rise or fall of the slit in front of the photographic recording apparatus, and a curve is traced on its revolving cylinder by the light from a lamp. A base line is obtained by the light from the same lamp being reflected on to the cylinder by means of two prisms contained in a tube. From the two lines traced, the extent of the rise or fall of the barometer can be ascertained.

168. Photographic apparatus, for registering simultaneously the variations of both the above instruments, Nos. 166 and 167.

1876. *Lent by the late Chas. Brooke, F.R.S.*

169. Self-registering Bifilar Magnetometer, with compensation for changes of temperature, and warm water envelope for testing the same.

1876. *Lent by the late Chas. Brooke, F.R.S.*

The compensation is effected by diminishing the lower interval of the double suspension, by means of the differential expansion of glass and zinc, in proportion to the diminished magnetic energy of the bar, due to elevation of temperature.

Records are obtained with this instrument by a method similar to that adopted in the magnetometer, No. 166.

170. Photographic Apparatus for registering the variation of No. 169 by means of a reflected pencil of light.

1876. *Lent by the late Chas. Brooke, F.R.S.*

171. Illustrations of curves, drawn by Brooke's magnetometers. In frame, 2 ft. 1 in. by 1 ft. 8 in.

1876. *Lent by the late Chas. Brooke, F.R.S.*

172. Photographic Self-registering Horizontal Force, or Bifilar Magnetometer, constructed in 1847, at the Kew Observatory, by Mr. Francis Ronalds.

1876. *Lent by the Kew Committee of the Royal Society.*

Described in the British Association Report for 1849.

The magnet, 15 in. long, is suspended in a loop of fine wire, by means of a pulley, forming a bifilar arrangement. It carries, attached to its lower side, a light brass bar, which moves a little shutter in front of an oil lamp, allowing a pencil of rays to pass through a hole in it. The light is then thrown, by means of a lens, upon a daguerreotype plate, which is steadily drawn upwards by means of a clock.

The curves upon the daguerreotype plates were sometimes etched in, and engravings subsequently worked off, or tracings were made upon sheets of gelatine, which, being preserved, allowed the silvered plates to be repeatedly used.

This instrument was superseded by the improved magnetographs erected at Kew by Mr. Welsh in 1857, which have since remained in almost continuous action.

The suspension frame originally fitted has been replaced by one not belonging to the instrument when in use.

173. Photographic Self - registering Declination Magnet, constructed in 1846, at the Kew Observatory, by Mr. Francis Ronalds.

1876. *Lent by the Kew Committee of the Royal Society.*

Described in the Philosophical Transactions for 1847, vol. i.

The magnet 2 ft. long, when in use, was suspended by a silken skein 9 ft. long; on its under side it carries a brass bar, from one end of which hangs a perforated metal plate, which, moving in front of a lamp, permits a pencil of light to fall upon a daguerreotype plate, carried slowly upwards by a clock suitably arranged.

The magnet is surrounded by a damper, made by electroplating a frame of mahogany with copper. Both are enclosed in double wooden cases, having both surfaces covered with gold paper.

This instrument was superseded by the improved Kew magnetographs, which have been in almost continuous action since 1858.

174. Mascart's Magnetic Apparatus.

E. 5 to 9.—1884. *Made by J. Carpentier, Paris.*

This apparatus is used for photographic recording. It includes :—

Declinometer.—This consists of a cylindrical copper cage with a graduated circle at its base, supported on a stand with levelling screws, and capable of motion round a vertical axis. On one of the sides of this cage is a circular opening, furnished with a convex lens, ordinarily of 1 metre focal length. A tube 17 centimetres in height, fixed by its base to a second graduated circle, has at its upper extremity a small windlass, to which is attached the silk thread by means of which the magnetic needle is suspended. This magnetic needle is of square section and 5 centimetres long, and the stirrup which carries it is furnished with a vertical mirror to indicate the displacements of the magnet. The stirrups are of two kinds; in one the mirror can be placed parallel, and in the other at right angles to the bar. Another vertical mirror just below forms part of the cage, and can be adjusted horizontally or vertically by two screws. By this mirror a base line is obtained.

Bifilar.—The Bifilar is constructed to measure variations of the horizontal component of the earth's magnetic force, and is very similar to the declinometer. The chief difference is in the mode of suspension and the direction of the needle. The stirrup which carries it has a bifilar suspension, the two threads of silk being kept at a distance of about 5 millimetres from each other. The two screws at the top are for regulating the length of the threads and for modifying the distance between them, so as to alter the sensibility of the instrument. The upper part of the

cage has a second graduated circle, furnished with a vernier and adjusting screw.

Balance.—The magnetic balance indicates the variations of the vertical component. This apparatus consists of a magnetic needle supported by means of knife edges on a surface of agate. The adjustment is made with the aid of an index, so fitted that it can be directed towards either pole of the needle to produce equilibrium. A screw nut, mounted on a vertical rod, allows the centre of gravity to be raised or lowered, and consequently regulates the sensibility of the needle. The balance is furnished with two mirrors, laid horizontally, one movable, the other fixed but capable of adjustment by screws. The whole is enclosed in a small cage. On the upper part above the mirrors are two apertures, on one of which is mounted a rectangular isosceles prism, one of whose sides is a little convex, so that it is equivalent to a converging lens of about 1 metre focal length: the other aperture contains a thermometer placed in a vertical position.

The Comparison Rule is used in graduating the photographic records, that is, in determining the values of the components of the earth's magnetic force from the curves traced on the recording plate. It is divided into millimetres, and is mounted on a copper stand; on this rule is a sliding piece, which carries a vertical circle with face perpendicular to the direction of the rule. This circle is made to carry a magnet, and is movable in a vertical plane. At one end of the rule there is a projection that can be raised or lowered, as required, by means of a screw.

The Clock is supplied with a lamp having slits in the metal caps of its three faces, by which light passes to the mirrors of the declinometer and magnetometers. It has also two right-angled prisms and a slit for receiving the reflected rays and passing them to the sensitized recording plate. This plate, which is marked for the 24 hours, moves by means of a rack and wheelwork in connexion with the clock train inside the case; and is protected from all light rays, except those coming from the instruments, by means of a wooden partition.

(*See* "Notice sur les appareils magnétiques de M. Mascart." Tolmer & Cie., Paris, 1883.)

175. Drawings of Kew Magnetometers.
In frame, 1 ft. 2 in. by 1 ft. 9½ in.
1876. *Lent by the Kew Committee of the Royal Society.*

176. Magnetarium for reproducing the phenomena of terrestrial magnetism and the secular changes in its horizontal and vertical components.

E. 21.—1894. *Designed and presented by H. Wilde, F.R.S.*

The instrument consists of two geographical globes, one rotating within the other, on separate axles. The outside of the

internal globe is wound with insulated copper wire, and mounted with its axis at an angle of 23·5° to the axis of the external globe, so as to revolve in the plane of the ecliptic. The under surface of the mapped globe is also wound with insulated wire, and the ocean areas are covered with thin sheet-iron to produce a difference between the magnetism of the land and ocean areas. Electric currents are transmitted round the wired surfaces of the globes by contacts with insulated metal rings fixed on the axles, and turning with them. By means of an epicyclical train of wheels, a slow differential motion is given to the internal globe, by which the principal phenomena of terrestrial magnetism and the secular variations of the declination and dip at London, Cape of Good Hope, St. Helena, and Ascension Island for the last three centuries are closely reproduced. The period of backward rotation of the internal electro-dynamic sphere required for the secular variations of the magnetic elements on different parts of the earth's surface is 960 years, or 22·5′ of a degree annually.

The instrument also shows (1) the inequality of the declination periods about the same meridians in the northern and southern hemispheres, as instanced in the short period of outward westerly declination at London (160 years), and the long period of outward westerly declination at the Cape of Good Hope (272 years), and St. Helena (256 years). (2) The single downward or upward motion of the dipping needle, for the double outward and return march of the declination needle, as instanced in the continued diminution of the dip in the British Isles during the westerly outward and return march of the declination since the year 1723. (3) The secular changes of the dip in opposite directions about the same meridian in the northern and southern hemispheres, as instanced in the dip diminishing in the British Isles and increasing at the Cape of Good Hope, St. Helena, and Ascension Island for the present epoch. (4) The rapid increase of the dip about the Atlantic node of the magnetic equator (17′ annually), as first indicated by Sabine in the Gulf of Guinea and St. Helena, together with the westerly progression of the node itself.

With the apparatus are tables showing results obtained with the Magnetarium, and diagrams of curves of equal magnetic variation and inclination, 1880.

177. Apparatus to illustrate the phenomena of terrestrial magnetism.

E. 47.—1886. *Made by Elliott Bros.*

It consists of a hollow iron globe, round the central portion of which is wound some insulated copper wire.

The globe is supported on a horizontal axis, attached to the two uprights of the frame. These uprights are furnished with small magnetic needles, which are free to turn in a horizontal plane above the globe.

If an electric current be sent through the wire, the directions of the needles vary as the globe is turned on the axis.

178. Globe, illustrative of the Earth's Magnetism, 1872. Designed by Staff-Captain F. J. Evans, R.N., F.R.S.

1876. *Lent by the Hydrographic Department of the Admiralty.*

On this globe four magnetic elements are exhibited:—

(i.) The absolute intensity, or "total force" of magnetism.
(ii.) The "magnetic foci," or points of maximum intensity, of which there are two points in each hemisphere.
(iii.) The magnetic equator, or line on earth's surface where the dip is zero.
(iv.) The "magnetic poles," or points where the dip is 90°, of which there is one in each hemisphere.

(i.) and (ii.) are expressed by lines of equal force in absolute measure (British units). (iii.) is shown by the gold band, and (iv.) by two studs.

The magnetic equator forms the boundary of the earth's "red" or "blue" magnetism, terms adopted to avoid confusion and to express the two kinds of magnetism, blue magnetism being that of the north pole of the earth and of the south end of a magnetic needle, red magnetism being that of the south pole of the earth and of the north end of a magnetic needle.

179. Terrestrial globe, showing magnetic meridians for epoch 1880, and general distribution of the secular change of the declination.

E. 126.—1886. *Prepared by Captain E. W. Creak, R.N., F.R.S.*

The meridians coloured red are drawn according to the results of observations of the declination, made principally during the years 1865–85, reduced to the epoch 1880. The blue lines round the terrestrial poles enclose areas in which no observations have been made.

SECULAR CHANGE.

Declination. The red arrows denote the direction in which the north or marked end of the needle is moving.

The white discs show the approximate positions of the foci of greatest change of the declination. The black lines are drawn through positions where there is no secular change of this element.

Vertical force. The red discs denote foci of greatest secular change in the vertical force, an upward force being marked with the sign −, and a downward force +. At the African focus, the north end of the dipping needle is moving upward about 14′ annually, at the South American focus downward about 11′.

Judging from analogy, another focus of upward vertical force exists near the north magnetic pole, or a focus of downward force near the position of the Siberian focus of total intensity.

A consideration of the foci of greatest secular change in the declination and vertical force shows the general angular motion of the north or marked end of a freely suspended needle as regards secular change. Thus at the declination foci the needle moves only in the horizontal plane, at the foci of vertical force only in the vertical plane, and at intermediate stations in the resultant of the two directions.

The north or marked end of the needles mentioned is identical with the "red" end of the needle, as proposed by Sir George Airy, late Astronomer Royal.

180. Diagram showing curves of Equal Magnetic Variation, 1871. Compiled by Staff-Captain F. J. Evans and Navigating-Lieutenant E. W. Creak, R.N.

1876. *Lent by the Hydrographic Department of the Admiralty.*

181. Maps, illustrating the distribution of the Earth's Magnetism. Prepared for the Polar Expedition, 1875.

1876. *Lent by the Hydrographic Department of the Admiralty.*

These maps are marked similarly to the globes above (Nos. 178 and 179). The earth's magnetism is shown by lines of equal total force in absolute measures (British units), and the position of the magnetic poles, equator, and regions of blue and red magnetism are marked.

In the same frame there are also three other maps showing the lines of equal magnetic dip, equal horizontal force, and equal variation. [The western variation is denoted by continuous lines, eastern by dotted lines.]

182. Diagram showing curves of Equal Magnetic Variation, 1880. By Staff-Commander E. W. Creak, R.N. Published under the superintendence of Capt. F. J. Evans, R.N., C.B., F.R.S. In frame 2 ft. 6 in. by 3 ft. 6 in.

1884.

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